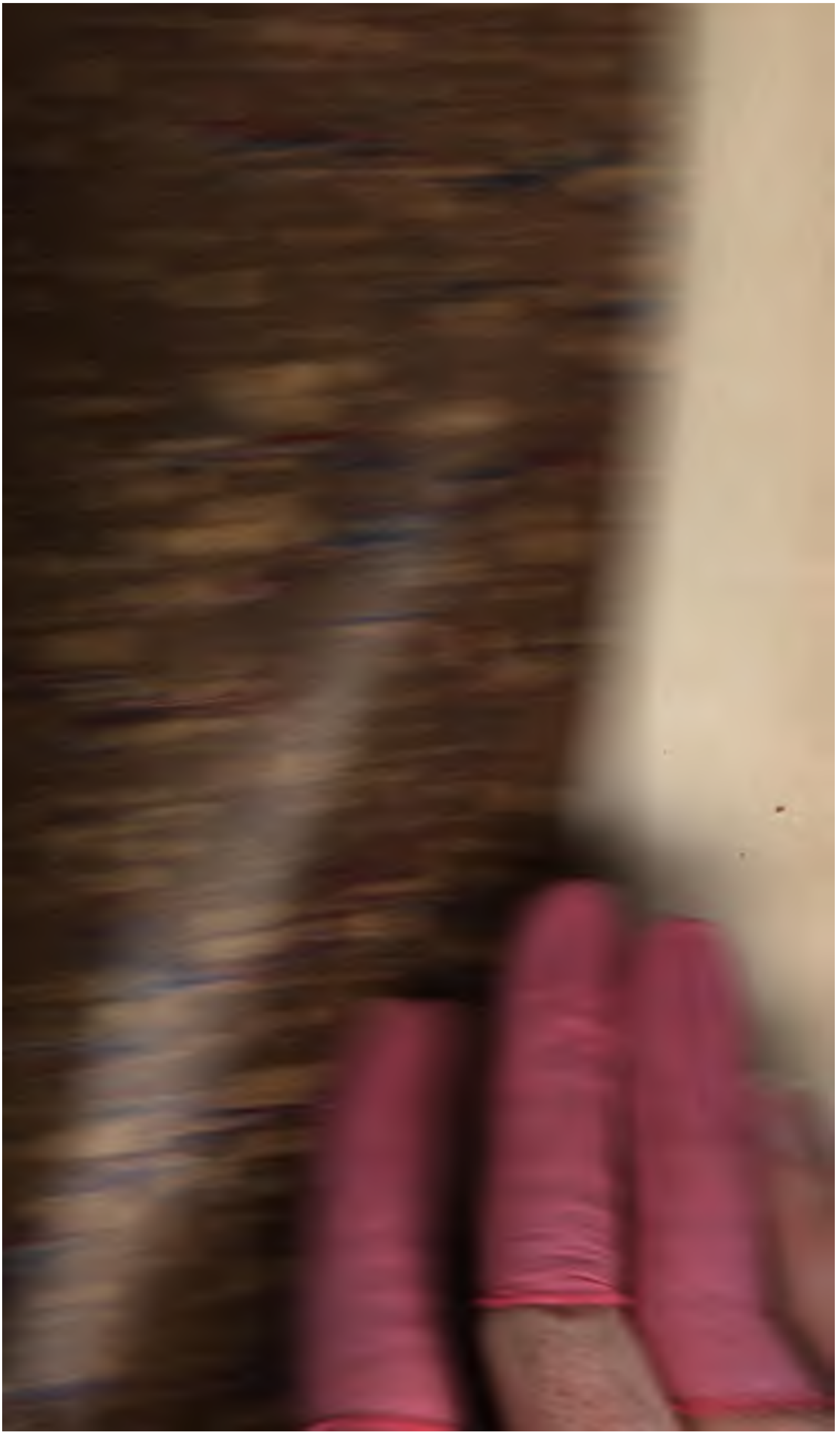

NATIONAL

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BIOGRAPHICAL MEMOIRS.

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PREFACE.

According to the rules of the National Academy of Sciences it is the duty of the President, upon the death of any member, to provide for the preparation of a biographical memoir of the deceased, by appointing some member to perform that duty, such memoir being subsequently read at a regular session of the Academy.

By direction of the Academy the Home Secretary has collected the memoirs that have been so prepared to the close of 1876, and has published them in the present volume. Others will be printed from time to time, as they are delivered, and will ultimately be combined into similar volumes.

Washington City, Dec. 1876.

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MEMOIR

OF

JOSEPH STILLMAN HUBBARD.

1823–1863.

BY

B. A. GOULD.

READ BEFORE THE NATIONAL ACADEMY AT NEW HAVEN, AUG. 5, 1864.

BIOGRAPHICAL MEMOIR OF JOSEPH S. HUBBARD

MR. PRESIDENT AND GENTLEMEN:—

The Constitution of our Academy, like the organic law of most Academies of Science beyond the seas, provides for the tribute of a formal Biographical Notice, pronounced in open session, in commemoration of each of our number who may be removed by death. For it is no unreasonable assumption that public benefit and individual incentives may be derived from the history of any man whose scientific services have rendered him worthy of admittance to your number.

It has been the will of God that the first place in our ranks made vacant by death should be that of JOSEPH STILLMAN HUBBARD, and in obedience to your instructions I am here to tell the simple story of his life;—not without a doubt of my own ability for the task, yet glad that the lot has fallen to my share, for none outside the narrow limits of his kindred could have held him dearer.

Upon our roll, Gentlemen of the Academy, are the names of venerable men, whose usefulness has extended through a period surpassing the total duration of most human lives, and side by side with these are the names of others, who were not yet cradled when the former were full of honors, and crowned with gray hairs. The years of our eldest and youngest member differ by more than half a century. Yet the first summons came, not to any of the great masters in science who give its lustre to the new gem with which an afflicted but regenerate land would fain crown her aching brows; not to those who might well claim to have finished the work on earth which their talents and opportunities seemed to mark out for them;—it came to one of the youngest in our ranks—the forty-sixth of the original fifty in order of age—to one whose work seemed chiefly in the future, and from whom we expected bright laurels for the Academy and for America.

When in April, 1863, we assembled for the great work of founding a National Academy, none was more hopeful, none more buoyant, none more impressed with the magnitude and import of our new duties, than he. It was the realization of the dream of his maturer years, the new Atlantis of his scientific aspiration, and his heart was full of bright anticipations, tinged with all the hues which a noble enthusiasm could bestow.

"A better Three Days for science were never spent," he wrote to his brother; and to his pastor in Washington, "The inauguration of this Academy marks the most important epoch ever witnessed by Science in America; *we* say in the world."

In less than four months after that meeting in New York, his generous, fervid heart had ceased to beat. He died 1863, August 16, twenty-one days before the completion of his fortieth year.

The custom has always seemed to me an eminently proper one, which prefaces the history of a life by some mention and notice of ancestry. For—whether we adopt the European notion that the ancestor ennobles his descendant by good deeds, or the perhaps more equitable Asiatic idea that honor flows in an ascending course, ennobling those whose nurturing care has thus borne fruit—the bond of lineage may not lightly be disregarded; and each day's experience teaches us anew, that "men do not gather grapes of thorns nor figs of thistles."

I may therefore say that our departed colleague drew his origin from the early founders of our race, from that sturdy stock which gave character to the Colony of Massachusetts Bay, and shaped the civilization of New England.

His first American ancestor, Mr. William Hubbard, came out at the age of forty in the "Defence," from London, in the year 1635, and soon established himself in Ipswich, Essex County, Massachusetts; which town he represented for eight successive years, from 1638 to 1646, in the Legislature of the Colony. In 1662, he removed to Boston, where he died in the year 1670, aged seventy-five years, leaving three sons, all born in England.

The eldest of these sons, and second in the line of descent, was the Rev. William Hubbard, a man of much note in his day. Born in 1622, he was but thirteen years old when his father brought him to the new world. He graduated at Harvard College in 1642, and was in 1658 ordained colleague of Rev. Thomas

Cobbett, in Ipswich, where he remained as pastor until his death in 1704; his kinsman, Rev. John Rogers, son of the President of Harvard College, acting as his colleague during the later years of his life.

This learned and good man was one of the first historians of the early troubles with the Indians. Two works on this subject were published by him in 1677, and subsequently republished in London in one volume under the title, "The Present State of New England." His "History of New England," left by him in manuscript, is preserved in the archives of the Massachusetts Historical Society, and forms volumes V. and VI. of their printed "Collections." In 1688, after the departure of President Increase Mather for England, he was commissioned by Governor Andros to officiate as President or Rector at the Harvard Commencement, being the oldest clerical Alumnus in New England; and as there were no graduates in that year, it is recorded in Sewall's Diary that he delivered an oration on the occasion, although this has not been transmitted to us.[1] His first wife, and the mother of his children, was Margaret, daughter of Rev. Nathaniel Rogers, and said to have been the great-granddaughter of that John Rogers who was burnt at the stake in Smithfield, 1555—although,

[1] That Rev. William Hubbard was a man of no small independence and decision of character, may easily be inferred from his works; but other indications of his mental and moral force are not wanting. In the ecclesiastical troubles of 1667, connected with the establishment of the "Old South Church" in Boston, he took strong ground and bore an active part; and on the passage of a vote of censure upon himself and his colleagues in 1670, by a committee of the Legislature, he was one of the number who answered with a protest of such ability and convincing force, that the Legislature replied by an ample apology.

John Dunton, who visited him in 1686, gives [Felt, Hist. Ipswich, p. 230] the following description of Mr. Hubbard: "The benefit of nature and the fatigue of study have equally contributed to his eminence. Neither are we less obliged to both than himself; he freely communicates of his learning to all who have the happiness to share in his converse. In a word, he is learned without ostentation and vanity, and gives all his productions such a delicate turn and grace . . . . that the features and lineaments of the child make a clear discovery and distinction of the father; yet he is a man of singular modesty, of strict morals, and has done as much for the conversion of the Indians as most men in New England."

according to that accurate investigator, Mr. Savage, this claim is not well substantiated.

The several successive generations of our colleague's ancestors seem to have been, without exception, men of moral worth and of influence in the community.

Rev. John Hubbard, in the fourth generation, was settled in 1698 at Jamaica, Long Island, where he was distinguished by a Christian charity and tolerance remarkable for those days. His son John settled in New Haven, where he served the community in the various capacities of Physician, Colonel, Representative, Judge of Probate, and Judge of Common Pleas; and his descendants have continued to reside in the vicinity of this beautiful and classic city.[1]

Here our colleague was born, 1823, Sept. 7 (in the ninth generation from the American founder of his family), being the second son of Ezra Stiles Hubbard and Eliza Church, of New Haven—parents to whom he was more than tenderly attached, and whose declining years were blessed by his thoughtful devotion. Of his father, I may quote his own words written three years ago: "My father has done his life's work well. Unable from feeble health to live the scholar's life to which he had been destined by his uncle, President STILES, and honoring learning next to godli-

[1] The line of descent is as follows:—

I. William, b. in England, 1595; d. Ipswich, Mass., 1670.

II. Rev. William, b. England, 1622 (H. C. 1642); d. Ipswich, 1794, Sept. 14; married Margaret, daughter of Rev. Nathaniel Rogers.

III. John, a merchant of Boston, b. Ipswich, 1648; d. 1710, Jan. 8; married Ann, daughter of Gov. John Leverett.

IV. Rev. John, of Jamaica, N. Y., b. Boston, 1677, Jan. 9 (H. C. 1695); d. 1705, Oct. 5. [See Thompson, Hist. of Long Island, 1st ed., p. 388; also Boston News Letter, No. 79, 1705, Oct. 22.]

V. Dr. John, of New Haven, b. Jamaica, 1703, Nov. 30 (A. M. Yale, 1730); d. 1773, Oct. 30; married, 1724, Elizabeth Stevens.

VI. Rev. John, of Meriden, Conn., b. New Haven, 1727, Jan. 24 (Y. C. 1744); d. 1786, Nov. 18; married, 1750, Jan. 25, Rebecca Dickerman. [See Meriden Historical Collections.]

VII. Isaac, of Meriden, b. Meriden, 1752, Nov. 22; married, 1782, Dec. 5, Jane, daughter of Thomas Berry.

VIII. Ezra Stiles, of New Haven, b. Meriden, 1794, May 13; d. 1861, Aug. 20; married, 1820, Dec. 13, Eliza, daughter of Josiah Church.

IX. Joseph Stillman, of Washington, D. C., b. New Haven, 1823, Sept. 7 (Y. C. 1843).

ness, he endeavored to give his children every advantage attainable for scholarship, devoting his life, labors, and scanty means to this one object. Precious is his memory."

From a most interesting and touching sketch of his early life, prepared by his admirable mother, I may be permitted to gather some of the incidents of his boyhood illustrative of the peculiar traits of his character—earnestness, enthusiasm, and self-forgetfulness, modified by a wholesome love of fun and frolic, a tender susceptibility, and an affectionate nature. From the whole account it is manifest that in childhood as in maturer life he made for himself a place in the hearts of all with whom he came in contact; and I think it may be said of him with literal truth, what is so rarely true even of good men endowed with far less force of character, that he had not an enemy in the world.

With him, too, the old and ever new experience came to his parents, of the early yearning of an intellectual child for books and knowledge, and they afterwards lamented that this dangerous tendency was not more carefully held in check. But although the danger of over-stimulating a receptive brain can hardly be exaggerated, and though the precautions of physical education were at that time comparatively disregarded among us—I see no reason for suspicion of any morbid precocity. I venture to make the following extracts from the interesting accounts kindly furnished me by his mother:—

"In his eighth year he suffered a severe course of lung fever, and for several weeks after the crisis was past seemed vacillating between life and death. After he began to convalesce, it was almost impossible to keep his active mind quiet enough to suffer the weakened frame to recover its tone. Pictures, books, toys, everything we could devise, were put into requisition to amuse him. His father saw one day in a store a curious piece of mechanism, a puzzle which he knew would delight the child—but it was an expensive article, and he hesitated if he ought to purchase it. But a second thought of the tired, weary boy decided the question. When he put it into Joseph's hand, as he sat bolstered up in bed, the child's eyes fairly flashed with delight. Seeing him so much amused at studying its intricacies, I left him . . . . and returning after a while found him utterly exhausted. He had taken the toy to pieces to ascertain its construction, and i trying to put it together again, had so used the little strength had gained as to leave us for many days to fear a fatal result. That was ever one of his peculiarities—not to rest until he understood the how and why of everything he saw, or at least had learned all that could be learned about it. . . . . It was about his ninth year that he began especially to develop his peculiar taste for mathematical studies and mechanics. Though he loved play dearly, and enjoyed it with zest for a little while, he had far rather spend his hours out of school in trying experiments, endeavoring to make machines, etc. . . . . One of his great efforts was to make a clock. He had been attracted by seeing his father wind up the time-piece, and had begged to examine it. A day or two after I found him in his room, surrounded by a quaint collection of bits of board, pasteboard, wire, lead, etc. To the question, 'What is the tinker about now?' he replied: 'Mother, I'm going to make a clock.' I told him we must ask his father for some tools, and perhaps he would succeed; and he did succeed —constructing a clock in all its parts, with face, hands, etc., and which went for a time, being duly mounted on the kitchen shelf, and for making which his only tools were a pair of scissors and a jackknife.

"After that, his father procured him a small chest of tools, and from that day he had full employment for every leisure hour. The attic was appropriated for his wood-work, and the back piazza for his crucibles, castings, etc. Most of his leisure time before entering college was devoted to making a telescope, which proved to be quite a good instrument, and which he sold to a gentleman from Catskill, soon after he entered college. He made also a camera-obscura, which afforded a fund of amusement to himself and his playmates, and a press for binding books. As long as his father lived he used the blank books with which the boy supplied him at this time.

"When fitting for college, while visiting some mechanic's shop, in pursuit of material or instruction, he came in contact with Ebenezer Mason, who was then one of Yale's enthusiastic astronomers, and at once there sprung up between the young man and the boy a kindly sympathy. Mason introduced the lad to his own chosen associates in study, invited him to their rooms for work, experiments, etc.; and from that day his scientific life began in earnest. Nothing could make him so happy as permission to spend the evening he could spare from daily lessons with Mason and Hamilton Smith; and, when in college, to be invited to watch shooting-stars or take observations with Mr. Herrick, was the greatest boon the world could afford him. His standing in college was above mediocrity, but not what he could easily have made it. His mind was so entirely filled with his own loved department of study, that he did not value college honors enough to give the needful attention to other branches.

"In his sixteenth year Joseph determined to take a pedestrian excursion. He set out to visit an uncle residing twenty or thirty miles north of us, and his father furnished him with all he thought needful for so short a trip. He had always kept us informed of his movements when away; and when six days had passed, and we received no intelligence from him, we began to be seriously uneasy. At length a letter came, mailed in Charlestown, Mass. He had heard Mason and Smith talk about a mechanic in Ware, who had given them much information about casting mirrors for telescopes, and had long wished to see the man for himself. So, after tarrying one night at his uncle's, he had wended his way up to Ware, and having learned all he could from the man he sought, had proceeded on foot to Charlestown a distance of 175 miles, in order to visit Bunker Hill."

In 1843, he graduated at Yale College. For a few months he remained at home pursuing his favorite studies, mathematics and astronomy; and in the following winter he taught for a while in a classical school. Early in 1844, he went to Philadelphia, as an assistant of Walker, who was then beginning his astronomical labors, and whose attention had been attracted by the bright promise of the earnest and gifted youth. Here the contagious zeal of Walker added fuel to the flame. Removed for the first time from the restraining influences of home, on which he had learned unconsciously to depend, he forgot all prudent care for himself. He observed with Walker at the High School Observatory all night, and computed all the day—and I need not add that his health soon gave way. From that time he was subject to a nervous excitability before unknown to him, and to an irregular action of the heart, from which he suffered much, and which finally exhausted his strength and energies—depriving him of that vigor of constitution with which he was originally endowed, and which might have arrested the progress of his last disease.

In the autumn of 1844, Lieut. (now Major General) Fremont offered Mr. Hubbard a position in Washington as computer of the observations for latitude and longitude made on his expeditions across the Rocky Mountains, and on the Pacific coast. These completed, and the interest of Prof. Bache, Capt. Fremont, and Col. Benton, being enlisted in his behalf by his successful and meritorious labors in Philadelphia and Washington, they obtained a promise from Mr. Bancroft, then Secretary of the Navy, that his appointment should immediately be made out for a vacancy in the corps of Professors of Mathematics in the Navy. He was commissioned 1845, May 7, and immediately assigned to duty at the Washington Observatory, of which he continued an officer during the remainder of his life. He was elected a member of the National Institute of Washington, 1845, January 14; of the Connecticut Academy of Arts and Sciences, 1849, October 24; of the American Academy of Arts and Sciences in Boston, 1850, August 15; and of the American Philosophical Society of Philadelphia, 1852, May 7.

It would be needless, gentlemen of the Academy, did taste not forbid, for me to describe to you at any length, the embarrassments of astronomers, stationed at the Washington Observatory, while under the charge of the late Superintendent. Few of you, if any, can have failed to appreciate the painful conflict between self-respect and official properties—between the emotions of the scientist, jealous of his country's reputation, and of the subordinate, whose duty in an establishment under military organization demanded tacit submission and apparent acquiescence, under a mortifying or atrocious policy. The sensitive nature of Walker found it impossible to endure the trial; but his pupil, Hubbard, struggled more successfully.

Would that I might with propriety express my keen sense of the deep debt of gratitude due from American science to those able and disinterested men, some of them, happily, still of our number, who bore the mortification of their position without flinching, that they might save the national scientific institution, which it was partially within their power to protect, from becoming a source of national disgrace. They toiled earnestly and judiciously for the sake of their hope that some small portion of their labor might bear fruit, though that fruit should not be plucked by them. They struggled against obstacles which would have deterred most men, in order that the noble instruments might render some service to science, or at least fail to be made implements of national disgrace. How well they succeeded, their record bears witness; and it will bear eternal testimony to their honor, when in its own good time history shall break the seals which the present day has necessarily affixed.

A single anecdote from many which might be told, illustrative of the state of things, may perhaps be pardonable now, although it would never have been publicly mentioned by our departed colleague, nor with his permission.

Professor Hubbard was one morning summoned to the presence of the Superintendent, who handed him a letter just received from Germany, and desired its translation. It contained the announcement of the discovery of a new comet, together with observations of its position on two successive days—an interval of eighteen or twenty days having of course elapsed since that time.

"I wish an Ephemeris of this comet," said he, "to be prepared without delay, for publication in the newspaper to-morrow morning." Hubbard respectfully suggested that three observations were requisite for computing the elements, and that even should the comet be found early in the evening, the intervals between the three dates would not be well adapted for the purpose. "Confound the elements, Mr. Hubbard!" said the Lieutenant, using some rather strong expletives; "I want none of your Elements, I only want an Ephemeris, and I wish you would compute it at once."

What the astronomer did under the embarrassing circumstances, I do not exactly know; but I suspect that the Ephemeris, which went to the *National Intelligencer*, was computed by methods neither of Olbers nor of Bessel!

The first published observations of Hubbard, so far as I am aware, were those by which, on the 4th of February, 1847, he confirmed the prediction of Walker as to the identity of Neptune with one of the stars observed by Lalande, 1795, May 10. This important discovery was made almost simultaneously by Petersen in Altona, and by Walker and Hubbard in Washington, and was of the highest importance for the accurate determination of the planet's orbit. By the employment of this ancient observation, and of the perturbations computed by Peirce, Walker was enabled to deduce the orbit of Neptune with a precision which leaves even now very little to be desired, and which surpasses that attained by any other computer to this present day.

At the Naval Observatory Hubbard was at once placed at the Transit-Instrument, with which he observed for four months; and was transferred to the Meridian Circle in September. Nearly nine hundred transit-observations by him may be found in the volumes of Washington Observations for 1845; and examination has shown them to possess decided value, in spite of the very unfavorable circumstances under which they were made. During the remainder of the year he was occupied with the adjustments, and in determining the Instrumental errors, of the Meridian Circle. The thorough description of this instrument and discussion of its corrections, in the volume for 1846, is from his pen; as also is the description of the Prime-Vertical Transit. Nearly one thousand observations with the Meridian Circle in 1846, as well as the discussion already cited, give token of his activity; but the equal labor of endeavoring to train and instruct many others—who were assigned to duty at the several astronomical instruments by the naval routine, although not inclined to astronomical pursuits, and indeed often affected with distaste for them—does not appear. Nor is any mention made of the careful and laborious organization and inception of a system of zone-observations, admirably devised and arranged by one of our present colleagues in connection with Professor Hubbard, although no public acknowledgment of their services in this respect was ever made, nor indeed claimed, by either of them. According to the plan of these zone-observations (Washington Observations, 1845, App., page 32), the micrometers of the Mural Circle, Transit-Instrument, and Meridian Circle were provided with additional declination-threads; additional transit-threads were inserted in the field of the Mural Circle, and the micrometer of the Transit-Instrument was rotated 90°; thus rendering it available for the measure of differences of declination. The several zones were made to overlap by 10′ in declination, and the instruments were to be employed simultaneously upon nearly the same declination, so that a portion of the stars observed by the Mural and Transit should be identical. Thus the Transit-Instrument would give standard observations of right-ascensions for an adequate number of stars in each zone swept by the Mural Circle; while this latter would in its turn give accurate declinations for a sufficient number of stars to determine the zones observed with the Transit. The Meridian Circle, meanwhile, was to go over the same ground independently, and thus all discordances which might arise from inevitable errors of observation would be satisfactorily disposed of.

These zone-observations were begun early in 1846, and continued till 1850, and even later; and a large amount of material was thus collected. The zones observed during 1846 with the Meridian Circle were reduced and published (under the superintendence of Mr. Ferguson of the Washington Observatory) in 1860; a portion of the Mural zones for 1846 had been reduced under the superintendence of Professor Coffin before he left the Observatory, and a considerable amount of labor had been given by Hubbard to the reduction of the Transit-zones for the same year. With these exceptions, nothing had been done toward the reduction, on the accession of the present Superintendent in 1861; although in the mean time a similar investigation had been planned by Professor Argelander, completely executed by him over all the practicable region south of Bessel's limit, and with a single instrument, and the results published in 1852, under the title of "Southern Zones."

But although the great labor bestowed by Coffin and Hubbard on the arrangement and execution of this grand scheme proved in a great degree futile—by reason of the neglect of the observations after they were made, by the loss of some of them, and by the reckless manner in which a large proportion of the work was done—the value of the plan and ingenuity of the arrangement remain the same. Had the valuable and delicate instruments, and the execution of the work, remained in charge of astronomers—rather than of gentlemen, who, however gallant and accomplished in their proper calling as lieutenants and midshipmen, could not reasonably be expected to do the work of astronomers without the requisite training, and frequently much to their distaste—had the large sums annually voted by Congress for the support of the Observatory been in part devoted to the reduction of these observations, and to the detection of the errors lurking in the observing books—they would have conferred high honor upon American science, and indeed formed by far the noblest achievement of practical astronomy in America. As it is, it has been found necessary to reject all the zone-observations made since 1849; the remainder consist of a curious combination of observations of the most delicate character and conscientious accuracy, with others which are literally beyond criticism; and the disregard of the original plan, and total lack of system in carrying on the work with the different instruments, has in great measure defeated the scheme, which prescribed that the same region should be swept by the Transit and the Mural. Thus the zones, when reduced, do not form a complete catalogue for the region over which they extend. Moreover, it has been found necessary to determine the zero-points, both for right-ascension and for declination, of a large proportion of the zones by observations of stars made during the last two years, at an expenditure of labor quite comparable with that of the original observations of the zones, and yet exposed to all the deleterious influences which may be exerted by the unknown proper motion of the comparison-stars during an interval of from fifteen to eighteen years. The reduction of these zones has been essentially completed, so that their publication may be looked for at no distant day; and of this work a portion of the original excellent organization, a considerable part of the earlier zones observed with the Meridian Circle, and two-thirds of all the good work done with that instrument is due to Hubbard.

Still, in my desire to do full honor to the generous and gifted man whose loss we mourn, I may not do injustice to the living; and at the hazard of incurring the disapproval of a colleague, happily spared to us, I must add, that for an amount of intellectual labor bestowed upon this work, greater even than Hubbard's, and for the exquisite elegance with which the observations with the Mural Circle were elaborated and made to give character and finish to the whole work, we are indebted to Professor Coffin, whose transfer from the Observatory to the Naval Academy was productive of more advantage to the latter institution than to the one from which, unfortunately for its welfare, he was taken away in 1853. Still his influence and example were not lost, and to Professor Yarnall we owe an ample series of admirable observations with the Mural Circle, which in connection with those of Mr. Ferguson at the Equatorial, saved the honor of a national institution, at the time when Hubbard was precluded by his health from observing, and after the departure of Coffin; and have furnished valuable observations in an unbroken line from this well-equipped establishment down to the time of its resuscitation under the original founder Captain Gilliss.

The most valuable of Hubbard's observations were unquestionably those with the Prime-Vertical Transit Instrument. This is essentially the counterpart of the one originally designed by Struve, and which has rendered such service at Pulkowa. It was thoroughly studied and mastered by Hubbard soon after his appointment at the observatory, and the scientific portions of the descriptions of the instrument were from the first chiefly from his pen. It was not, however, till the beginning of 1848, a year and a half after observations with the Prime-Vertical Instrument had been commenced, that he was officially assigned to its charge. The attainment of some definite result concerning the long mooted annual parallax of α *Lyræ*, which passes within 15′ of the zenith of Washington, was an especially cherished problem. For many years he labored towards its solution, in spite of serious and most vexatious obstacles. But the maxima and minima of the annual parallax occur at seasons very unfavorable to observations in the climate and atmosphere of Washington; and it was chiefly due to this fact, that some result was not long since attained. At the regeneration of the Observatory in 1861, he was again full of hopefulness and confidence of an early solution of this favorite problem, as well as sundry others. "Your rejoicing," he wrote, "cannot exceed mine; for it is a constant gratification to see order quenching chaos, energy overriding the old slowness, and, above all, our own science raising her triumphant head, and banishing the old humbug." Even at that period of his domestic bereavement and loneliness, it needed only the unwonted consciousness that Astronomy might be protected at the only national Observatory in the land, to reanimate his spirits, and give him a new stimulus to exertion. The Prime-Vertical Instrument, like the others, was soon put into complete order, and the traces of early misuse thoroughly removed; and in March, 1862, he began a new series of observations of α *Lyræ*. During the period of this series Hubbard completed an exhaustive discussion of the influence of irregularity of pivots upon the level-reading at different altitudes; a determination of the effect and amount of flexure by comparisons of the error of collimation deduced from reversing the telescope on a star with that resulting from reversals on the image of the threads reflected from mercury in the nadir. He had re-determined the value of the level divisions, had removed some serious discordances arising from a faulty construction of the level, and had completed tables for the more convenient reduction of the observations.

This series of observations he intended to continue for several years, but an overruling Providence willed otherwise. His last observation was on the 8th of July, 1863, not sixteen months after the first. Happily he was favored with an able and skilful collaborator in Professor William Harkness, and found a worthy successor. The series is continued by Prosessor Newcomb, than whom none is more competent to carry out the plans of his lamented associate, with all the success that scientific ability or earnest devotion can insure.

Professor Newcomb has investigated the probable error of Hubbard's observations of α *Lyræ*, and finds that of a single observation to be but $0''.155$.

In the early part of the year 1849, it was my privilege to become pesonally acquainted with Professor Hubbard, and to begin a friendship which knew no cloud until the last sad severance of all earthly ties. For his affectionate solicitude in time of sickness, his sympathy and support in evil days, his cordial aid in difficulty, and his encouragement in all good works—a debt is due to his memory which words cannot express, and which, alas! this life affords no opportunity of repaying.

Without Hubbard's cordial approval, the plan of the *Astronomical Journal* would probably not have been carried into execution; certainly it would not at the time when it was actually begun. He aided it in every way—by the promise of investigations for its columns—a promise amply fulfilled—by stimulating others both to contribute and to subscribe—by frank criticism, by generous incitement and discriminating commendation. No one could have felt a deeper interest in it than he, and of whatever service it may have rendered, a large proportion is to be credited to him alone. The earliest letter from him in my possession, dated June 8, 1849, is almost wholly devoted to a dicussion of the various plans we had previously orally debated.

In the summer of 1849, these plans were essentially matured, and after discussion with Bache, Peirce, Henry, Coffin, Walker, Chauvenet, and others almost equally interested, though not themselves engaged in prosecuting the same departments of inquiry (prominent among whom were our two honored Secretaries, and the Editors of the American Journal of Science), it was decided to give its origin a sort of national character by causing the first public suggestion to emanate from the American Association for the Advancement of Science, which held its second session at Cambridge in August, 1849. This work Hubbard took cordially and zealously in hand. He prepared a communication, which he laid before the Association [p. 378], representing the importance of the proposed undertaking, and the services which it might render in the development of astronomy and its kindred sciences at that critical period of our national growth. At his suggestion a committee was appointed to consider the subject, and to bring it to the notice of those interested in the advancement of astronomy. He afterwards prepared a Prospectus, and labored earnestly and with effect, for its wide circulation.

The six volumes of the Journal contain more than 210 columns of valuable contributions from his pen—and twice during the Editor's absence from the country did Hubbard assume the control and editorship.

The first extended computation of Professor Hubbard consisted in the determination of the zodiacs of all the known asteroids, except the four previously published in Germany. In November, 1848, he presented to the Smithsonian Institution the Zodiacs of *Vesta, Astrea, Hebe, Flora,* and *Metis;* and to the first volume of the Astronomical Journal, he contributed those of *Hygea, Parthenope,* and *Clio,* making the list complete up to that time. That of *Egeria* followed, soon after his satisfactory determination of the elements; and although he published no others, it was his intention as well as endeavor to prepare the zodiac for each successively discovered asteroid. These zodiacs give for each planet —as suggested by Gauss, and computed by him for *Ceres, Pallas,* and *Juno*—the northern and southern limits of its geocentric position for each right-ascension, and enable us in many cases to draw immediate inferences as to the possible identity of any recorded star with the planet in question. It is much to be desired that the series of asteroid-zodiacs should be completed, and a key thus furnished for the solution of many interesting questions of identity, which have occurred in the past, and must present themselves hereafter.

None of you, Gentlemen, can fail to recall the magnificent spectacle exhibited by the great Comet of 1843. Through the early evenings of March, it trailed like a gorgeous banner of flame across the western sky, the first visitant of its kind within the memories of many a full-grown man, and rekindling the awe and wonder of those, whose impressions of the cometic glories of 1807, 1811, and 1819 had become dimmed by time. Its magnificent train extended at nightfall nearly parallel with the horizon through an arc of some 40°, rivalling the later, though perhaps equally splendid, manifestation of the great Comet of 1858. So great indeed was its brilliancy while in close proximity to the sun, that it attracted the attention of the public at high noon in various parts of North and South America both on the day of its perihelion, and on the day following. It was seen at 11 o'clock on the morning of the 27th, at Conception, and measurements of its distance from the sun were made on the 28th, both in Maine and in Mexico; the tail being visible to the length of a full degree, at 3 o'clock in the afternoon of that day. The attempts of astronomers to satisfy the observations led to results singularly diverse. Only one characteristic of the orbit seemed beyond question—the extreme smallness of the perihelion distance. The close resemblance of its parabolic elements to those deduced by Henderson for the Comet of 1668, could not fail to attract attention, and the elements obtained by Peirce from the very unsatisfactory observations of the Comet of 1689, which have come down to us, exhibit also a decided similarity. Both Capocci and Claussen, believing in its identity with both, found themselves able to satisfy the observations by an ellipse of seven years' period. Encke, Walker, and Anderson found that the observations could be closely represented by a hyperbolic orbit—Boguslawski in Breslau advocated a period of 147½ years—Walker finally decided in favor of an ellipse of 21¾ years—while Laugier and Mauvais in Paris, Nicolai in Mannheim, and others, found the probabilities strongly in favor of the period of 175 years—which I cannot but believe to be the true one.

This magnificent object fired the zeal of Hubbard, already fascinated as he was with astronomical study and imbued with the spirit of research. He was within five months of graduation at Yale, and, from that time, he looked forward to a thorough and decisive investigation of the path of this comet, as his most favorite problem. And although some six years elapsed before he found it within his power to begin the long-desired research, he then prosecuted it with an earnestness which showed no loss of interest or of enthusiasm.

In December, 1849, he published the first part of this masterly discussion of the Orbit of the Great Comet of 1843—an investigation begun only a few months before, but hastened for the sake of an early contribution to the Astronomical Journal. This paper occupied a part of eight numbers, the conclusion appearing in July, 1852. It seems to me safe to say that the orbit of no comet of long period has been more thoroughly and exhaustively treated than this. All observations of the comet, of whatever kind, whether before published or obtained from the manuscripts of astronomers, were subjected to rigorous scrutiny, and were winnowed with a painstaking fidelity which would have surpassed the patience of most men. Especially were the very important sextant-observations, made in the daytime on the 28th of February by Captain Clarke, at Portland, Maine, and by Mr. Bowring, at Chihuahua, discussed with extreme care, and made, after sundry corrections, to exert an important influence upon the resultant orbit.

First forming normal places by the aid of one of the approximate parabolas at hand, Hubbard computed elliptic elements by the ordinary Gaussian method, and thus obtained new normals. Determining for these the coefficients of the variations of the elements relatively to the variations of the geocentric co-ordinates —and, for the sake of control, both by Bessel's method and by that of Goetze, he deduced the variations required for satisfying the new normals, and thus arrived at a second set of elements.

Repeating the process, and computing ten new equations of condition for new normal places, he obtained a third and fourth ellipse, the latter by the assignment of weights to the several normals. The amount of outstanding error was thus reduced to a very small quantity, and the orbit was sufficiently accurate to correct the sextant-observations, and decide sundry points left ambiguous by the observer. Thus he found which limit of the sun had been compared with the comet at Chihuahua, and was able to make the assumption of an error of two minutes in one of the recorded times of observation, and thus both to render the observations accordant, and to show their value. In a similar way the untrustworthiness of another sextant-observation was made manifest, and thus prevented from vitiating the computations. The errors of two sextant-measurements in each place were thus shown to lie within the limits of good observation, and the aid of these very important auxiliaries secured.

The disturbing forces were computed for each of the six large planets for each fourth day during the period of the comet's visibility, and with the series of osculating elements thus obtained, he determined the discordances of every accessible observation. Here, as everywhere in Hubbard's work, we find the indication of his scrupulous care in controlling his computations by the independent employment of different formulas, and of the tact by which he adapted various methods to his purpose; this peculiarity, as well as his exquisite elegance in the mechanical arrangement, and the beauty of his chirography reminding one continually of Encke, many of whose scientific characteristics seem equally to have belonged to Hubbard, though the fulness of years and opportunities happily accorded to the accomplished astronomer of Berlin were denied to our departed associate. True to his nature, he computed all the anomalies and radius-vectors in duplicate, once by means of a manuscript table to supply the reductions needed for Nicolai's formulas, which proved more convenient than Barker's table for an orbit of so small a perihelion distance, and then again by means of the Besselian reduction of the parabola to an elipse.

New equations of condition were now formed, sixty-six in number—weights were empirically assigned to each, and a fifth system of elements thus found which absolutely represented the Portland observation, and satisfied the two Chihuahua altitudes so admirably that the greatest discordance of the five amounted to but 37″, while the probable error of a normal place amounted to 16″. Separating the observations made with a ring-micrometer from those obtained by the filar micrometer, he was able to assign more accurate weights to the several measurements of each co-ordinate, and found, as might have been anticipated, that the probable error with the ring-micrometer did not much exceed that with the filar micrometer for differences of right ascension, while it proved to be nearly in the ratio of 7 to 10 for differences of declination.

By a repetition of the process, after assigning carefully computed weights, as above mentioned, to sixty-five normal equations of condition, Hubbard obtained by the method of least squares a sixth system of elements, which gave the best possible representation to the entire series of observations, and reduced the probable error of a normal place to less than 13″.

Here the investigation might well have rested; for the effect of terms of the second order, both in the perturbations and in the comparisons, might fairly be considered as removed, and the sums of the squares of the residuals were a minimum. But Hubbard was not content to leave any investigation, where there seemed an opportunity of prosecuting it further with success; and since the incorporation of observations made with the ring-micrometer had increased the probable errors of the results, and since the series with the filar micrometer extended through the whole period of visibility excepting the observations by daylight, he passed on to still another determination from the filar-micrometer observations alone combined with the sextant-observations of February 28. From these he constructed eighty-three new equations of condition, determined a seventh series of elements, reducing the probable error of a single normal to less than 8″.5, and assigned for each element its probable error. The period corresponding to these final element was somewhat more than five hundred years, and it became a problem of much interest to determine to what extent the resultant period might be varied consistently with the probable limits of errors of observation. This Hubbard solved most thoroughly by an ingenious method of determining the variations of each of the elements, of the probable errors, and of each normal place, as a function of the variation of the eccentricity. So that by substituting in these expressions the change of eccentricity corresponding to any suspected period, a few minutes of figuring will give us the corresponding elements, the probable error of normal places, and the individual discordances of observations. This substitution he carried out himself for the period of one hundred and seventy-five years, and found that it implied a probable error of $11\frac{1}{3}''$ for a single observation, and no individual discordances beyond the limit of reasonable error; although, to be sure, a certain "rate" seems to be indicated on this assumption by the earlier observations. The limits of periodic time consistent with its observed geocentric path were thus shown to be extremely wide; and Hubbard closed by suggesting that the want of coincidence between the centre of gravity and the centre of apparent condensation, as well as the operation of polar forces in the comet itself, might perhaps modify deductions drawn without consideration of these possible influences.

I have not hesitated, Gentlemen of the Academy, to describe this valuable memoir with a minuteness of detail quite unsuitable for a popular address; both because its masterly completeness and elegance render it a model investigation of its class, and because these qualities were so characteristic of our late colleague that a somewhat minute description seemed well adapted to exhibit his habits of mind and mode of research. Preserved in the Library of Yale College are three quarto volumes containing the actual numerical computations—all executed with marvellous neatness and a beauty of penmanship approaching the elegance of copperplate engraving—all arranged in due order, and in the form most convenient for reference, and all bearing the strong impress of the man. Indeed, in every one of his manuscripts we may see the reflection of his own cultivated and tasteful mind, in which there was no slovenly corner, or ill-finished record.

Hubbard's next investigation of magnitude was upon Biela's comet. Four quarto volumes, filled with neat figures, lie before me as I write, containing his researches concerning the orbit of this most interesting body. They are a priceless and treasured memento of our departed friend, which I owe to the thoughtful kindness of his family; and it is not improbable that four or five years hence they may facilitate the discovery of the origin and nature of the mysterious transformations which this singular comet has undergone, and may aid in the detection of the unknown laws controlling its physical structure.

It is known to you all that Biela's comet, as it is generally called, is one of short period, performing its entire revolution in about $6\frac{3}{4}$ years. It was first seen in 1772, by Montaigne, who made three or four imperfect and untrustworthy estimates of position, and it was observed four times, quite unsatisfactorily, by Messier. In 1806, it was detected by Pons; and the general resemblance of its orbit to the approximate one deduced for the comet of 1772, attracted immediate attention. Bessel and Gauss computed elliptic orbits on the supposition of identity. The latter found the apparent path as well represented by an ellipse of 4¾ years as by his best parabola, thus suggesting the probability that there had been six intermediate returns. The places observed in 1772 were, however, not so well satisfied by an ellipse of so short a major axis, and therefore while the hypothesis of identity seemed plausible, it could hardly be considered probable. It was not until 1826 that the comet was seen again. In that year it was independently discovered both on the 27th February, by Von Biela, an Austrian captain, on duty at the fortress of Josephstadt, and by Gambart in Marseilles, ten days later. Upon the first computation of the orbit, each recognized the identity of the comet with that of 1806, and the true length of the period became manifest.

The next return, in 1832, was successfully predicted by astronomers; at the following one in 1839, it was not discovered; and in the winter of 1845–6, a predicted return was for the second time observed. But here an unexpected and anomalous phenomenon was exhibited. The comet, which was detected at the close of November, was before the end of December seen to be double, and the two components became apparently further and further apart, until, at the end of March, their distance from one another amounted to more than 14′.

It was of course immediately maintained by some that an explosion had occurred, and it became a question of great interest to all astronomers, when, how, and through what agency the separation had been brought about. And yet another curious circumstance was this: that whereas the northern and preceding component was at first so decidedly the fainter of the two as to receive the name of the "companion," while the southerly one was regarded as the comet proper;—yet this companion, or northerly component, gradually increased in brilliancy, until about the time of perihelion-passage, surpassing the primary nucleus for several days, and then again diminishing in relative brightness so long as observations could be made.

Hubbard, who had observed this comet at Washington early in January, 1846, had been deeply impressed with these inexplicable phenomena, and no astronomer looked forward to its return in 1852 with more anxious interest than he. Would two independent comets be found traversing the same path? or would the phenomenon of a double nucleus be again exhibited? or would the two components manifest mutual relations analogous to those of satellite and primary, or at least to those of binary stars? Would it be possible for observations of each component at the coming perihelion passage to be combined with those made at the last return, so that an ellipse could be deduced for each, and the point of intersection thus determined? These and many similar queries were often discussed; and immediately on the completion of his paper on the comet of 1843, he began his preparations for an equally thorough investigation of Biela's comet so soon as its approaching return to the sun should have been thoroughly observed.

For a month previous to the detection of the comet, Hubbard had been engaged in the preparation of an ephemeris to insure its discovery at as early a date as possible, and had succeeded in obtaining an orbit decidedly better than Santini's, which was the best existing. But the discovery of the comet rendered the publication of this ephemeris unnecessary.

On the 26th August, 1852, Father Secchi, at Rome, while searching for Biela's comet in the neighborhood of the place indicated by Santini's ephemeris, discovered a very faint nebulous comet somewhat more than $4\frac{1}{2}°$ from the place predicted for Biela's, and was able to fix its position with great accuracy by its transit over a small star of the 9–10 magnitude, which it covered at one time so centrally that the comet could only be recognized by the circumstance that the star seemed enveloped in a faint nebulosity. "I do not know," he adds, "whether this is a new comet or a portion of Biela's, which was divided in the beginning of 1846."

There seemed but little room for reasonable doubt that this was really Biela's comet, or one of its component parts; since its position, though varying from the ephemeris, was nearly in the same orbit, and the amount and direction of its motion were what might have been expected. But all doubt was removed three weeks later, when Professor Secchi detected the other portion of the comet, following its predecessor by about half a degree of right-ascension, and about half a degree further south, and fainter even than the other. Owing to this extreme faintness of both portions, observations could only be continued for a little more than ten days after the discovery of the second component. The last return to perihelion took place in 1859, but the position of the comet was so unfavorable, that, although ephemerides prepared by three independent computors, one of them Hubbard himself, agreed very closely, and the most powerful telescopes of the world were occupied in the search, the comet was not seen.

With this brief sketch of the history of our knowledge of Biela's comet, I may, without entering into close detail, describe Hubbard's labors and researches concerning it. His published Memoirs on this subject are three in number, in addition to sundry smaller communications on special points; such as one in which he corrected a serious error, which had found its way into the best European computations of the perturbations in 1845–6, and explained its probable origin; and a publication of the valuable manuscript observations made by Professor Challis in Cambridge, England, during the same period, and sent by this distinguished astronomer to Professor Hubbard for employment in his investigations.

The first of these Memoirs is entitled, "On the Orbit of Biela's Comet in 1845–6." In this, as in every other memoir of its author, the same searching thoroughness and scrupulous accuracy are manifest which I have recounted concerning his investigation on the comet of 1843. All known observations were employed, no appreciable refinement of method or computation was neglected; and the materials were so fully and completely discussed that it is improbable that any results can ever be drawn from them which he did not himself deduce. The principal results of this memoir, in addition to the discussion of all the observations, consisted in the definite determination of elements for each component, together with their variations for any variation of the adopted mean motion; and in the discovery that by far the greater part of the difference between the two orbits might be represented by a variation in the mean anomaly alone. The residual errors implied by this assumption are very small, much less than the errors of individual observations, and in no case exceeding 8″; but they are nevertheless too symmetric, and too large for his normal places, and he points out, moreover, that some difference must necessarily exist in the mean motions.

In a letter of about this date (1853, June 8), he writes, jestingly: "Biela slides on smoothly. I don't work now, as on '43, wearily and with a *D*♆, nor boldly and with *D*φance *D*☊ing a change of Inclination, but *D*μrely. An allowable change of 0''.34 in the mean motion will give the places in 1852, within 24'' + the error of Santini's perturbations, provided I am right in assigning the nuclei relatively to each other; but it is not so easy to tell which is which, as I had supposed."

Hubbard's published investigations reached this point in the summer of 1853; and he was leisurely preparing the materials for a continuance of the work, when the Imperial Academy of Sciences of St. Petersburg, in December of that year, offered its astronomical prize for just such an investigation as that on which he was engaged. The distinguished head of the Observatory at Pulkowa wrote specially to suggest the publication in the United States of the Programme for the prize; and it may well be suspected that the very able discussion which Hubbard had already given might, at least in some degree, have tended to assure the astronomers of the Imperial Academy that competent men were already enlisted in the investigation, whom the liberal prize might at once stimulate and reward. And in view of the laborious and extended computations, which the solution of the problem would entail, a period of nearly four years was allowed for the preparation of the memoir. Many of Hubbard's friends desired him to compete for this prize, which I think there is no reasonable doubt would have been won by the memoirs which he subsequently published in America.

But Hubbard's delicate health, together with his earnest desire that whatever he might do for science should inure to his own country's service, prevented him from yielding to the temptation. He considered the matter for a brief period, and then decided that he "ought not to work against time," and the close of his researches was not reached till 1860.

The second paper, published in July, 1854, is entitled, "Results of additional Investigations respecting the two Nuclei of Biela's Comet." In this short, but very elaborate and important memoir, Hubbard discussed the observations of each nucleus in 1852, determining elements for each. And he arrived at the very remarkable results which seem now incontestable, "that notwithstanding the increased mutual distance of the two nuclei, their alternations of relative brilliancy were much greater than those noticed in 1846; so great indeed, for several days, as to amount to alternations of visibility from day to day;" and that the observations at Berlin, 1845, November 29 and December 2, were of the primary nucleus, the second being invisible to the observers; while those of Challis, December 1 and 3, were of the secondary, the first being unseen. So that it is clear, both that we are in possession of observations of the second nucleus, made in the beginning of December, 1845, before the existence of two nuclei was suspected, and that even at that time occurred those singular alternations of light which were repeated in 1852. Furthermore, he made it highly probable that the preceding component, in 1846, was identical with the following one in 1852, and *vice versâ;* and finally, that the separation of the nuclei must have occurred not far from 316° of heliocentric longitude, corresponding to a time about five hundred days before the perihelion passage of 1846.

At the close of 1858, Hubbard published a short paper containing a condensed notice of the condition of the problem, together with new elements for each nucleus, and an ephemeris for each at the approaching return of the comet to perihelion. This I have not counted as one of the Memoirs. His third and last paper on the subject appeared in May, 1860, under the title, "On Biela's Comet." It consists first of an admirable history of all our knowledge of this comet, with full references to the original sources, and presents an excellent specimen of what might be called condensed detail. Next it contains an elaborate discussion of the observations and orbit for every recorded appearance. And in the discussion of the last appearance in 1852, he brought to light a new illustration of the mysterious alternation of brilliancy between the two nuclei. For he showed, that when, on the 15th of September, Secchi found both nuclei and determined the position of one of them, the new one being too faint for observation, this so-called "new one" was the identical nucleus which he had discovered in August, and had been observing ever since; while the brighter of the two had then just become visible. "On the 16th, the southern nucleus alone was visible; on the 17th and 18th, only the northern; and finally, on the 19th, both were observed by Secchi. The double observation was repeated at Rome and at Pulkowa, on the 20th, 23d, and 25th; while on the 21st only the southern, and on the 22d only the northern, was visible. We thus have a most interesting repetition of the alternations in 1845–6, which now appear more remarkable only in consequence of the extreme faintness of the comets, which was such, that the slightest change of light sufficed to carry them within or beyond the scope of vision." (*Astron. Journal*, vi. 140.)

Finally a recapitulation of the final elements for each nucleus, and for all the observations and normal places, exhausts the sum of our present knowledge of Biela's comet, and leaves us ready for the new investigations which its return eighteen months hence will require.

Another extended investigation by Hubbard is that upon the Fourth Comet of 1825. Hansen had long ago found that the observations before and after perihelion seemed better reconciled by an ellipse than by a parabola; and Hubbard undertook the collection and discussion of all the observations in the hope of some definite determination of the major axis. This investigation occupied much of his time at irregular intervals for five or six years, and was finally published in the spring of 1859. In this, as in most of these cometary investigations, a leading object was to learn whether the motions of the comets, distinguished by their magnitude or varying aspect, or by any other striking peculiarity, would prove in all cases amenable to the law of gravitation alone. In the case of the comet of 1825, no special fact of general interest was elicited; but negative results, though less interesting, are attained with no less labor and skill than positive ones, and are often scarcely less important. Suffice it to say of this memoir, that it is complete, and apparently exhaustive; that the elliptic character of the comet is fully demonstrated, although its periodic time must be exceedingly long; and the material deducible from past observation lies ready for the hands of the future investigator.

I have now spoken, Gentlemen, at sufficient length of the larger and more extended memoirs of our departed colleague, and have described their characteristic features. Of his minor contributions to astronomy I need say no more than that they resemble the larger ones in thoroughness and neatness of conception. The columns of the Astronomical Journal, and the pages of the Washington Observations, are full of them: elements and ephemerides of many a comet and many an asteriod, elegant and appropriate suggestions, generally relating to methods of computation, or ingenious devices for attaining a desired end with economy of labor.

In the excellent tables appended by Professor Coffin and himself to several volumes of the Washington Observations; in the reduction and discussion of the geographical observations made by Lieutenants (now Major-Generals) Frémont and Emory on their various expeditions; in the thorough investigations of the several instruments successively placed in his charge—the accuracy and conscientiousness of Hubbard still bear fruit for us.

One of his latest labors was an unpublished investigation of the magnetism of iron vessels, and its effect upon the compass, upon which he was employed nearly to the time when a Permanent Commission appointed by the Navy Department undertook the same research upon that more extended scale, which the same gentlemen have continued till the present time in the form of a committee of the National Academy.

No description of Hubbard's intellectual character could be regarded as complete, that omitted one predominant trait which pervaded all his opinions, and lay deeply rooted in the very foundations of his nature. I mean that deep love of truth and loathing of all false assumption, which may be said to bear the same relation to honesty that honesty bears to what is called "worldly policy." There were few things which his modest and tolerant spirit could be said to hate; but he did hate sham, humbug, and charlatanism with all the energy of his soul. He never claimed honor, rank, or position for himself, although he hastened to accord all these to others far less worthy than he; but he was restive at the sight of scientific rewards unworthily bestowed by incompetent tribunals; and his sterling patriotism and sense of justice not unfrequently united in paining him when—

> "He saw the holy wreaths of Fame
> Profaned to deck ignoble brows."

Thus far, gentlemen, I have endeavored to describe Professor Hubbard to you as a man of science—showing you the early efforts of his mind, and the eager pursuit of knowledge which characterized even his boyhood. We have seen what he had accomplished at the age of thirty-nine; and alas! how much more he promised for the future which we hoped for him. But though all this is done, I feel that the more difficult part of my duty to his memory remains undone; and I approach it with yet greater distrust of my ability to do it aright. It is comparatively an easy task to trace the working of his mind, and the results of his studies; but to show him as some of us knew him, as a son, a brother, a friend, a Christian, to do him justice without trespassing on that privacy which none valued more highly than he, requires a hand of equal delicacy and skill. One assistance at least the biographer of Hubbard may justly feel to be accorded him—that in that life there is no record to be concealed, no page to be glanced at and quickly closed with pain. His only choice is what to show, not what to hide.

Our colleague had a kindly, gentle nature, and an affectionate regard for all around him. He made his own opportunities to help and cheer others, instead of waiting for them. Was a friend successful, he rejoiced with a cordiality that made him twice happy; in sorrow, he mourned with him, and with a sympathy that half lifted off the burden. One of the strongest affections of his life was for his mother. He showed her not only the natural affection and tenderness of a son, the respect due from youth to honorable age, or the attachment which old and cherished associations awaken, but to the very last he made her his confidante and counsellor. His deepest thoughts and highest aspirations, his struggles and his joys, were alike intrusted to her; a precious deposit, which her heart knew how to keep and ponder.

Professor Hubbard was married at the age of twenty-five to Miss Sarah E. L. Handy, of Washington, on the 27th of April, 1848. Few men were more fitted than he to enjoy the comforts of a home, or could better appreciate the blessings of his new relation; but there were many clouds to overshadow the horizon, as he himself says in one short note, whose pathos only those can understand who know that it was but once or twice in a lifetime that a murmur escaped his lips. Upon the threshold of his home stood always that dreary visitant, Ill-health, whose dominion over both mental and physical content most of us know too well. Hubbard's own health was never certain, but his wife was a far greater sufferer; and often, unknown to herself, her troubles weighed too heavily upon his over-tasked mind and sensitive heart. Even pecuniary embarrassments, those petty cares that, unlike deeper sorrows, fail to brace the mind they attack, were not wanting to sting his delicate and generous spirit. Each day their peculiar circumstances compelled new outlays, to be defrayed only from means already too slender. We can appreciate their struggles, without prying too closely into what he might have wished forgotten. We can see the student compelled to forego his cherished pursuits, the man of tender sensitiveness wrung by the sufferings of those nearest him, the invalid whose frail health varied with each new trial. We can see all this; but to a spirit such as his must have come many a compensation, many a blessing won from the dark angels by bitter wrestling.

> "For that high suffering which we dread
> A higher joy discloses;
> Men see the thorns on Jesus' head,
> But angels see the roses."

After eight and a half years of married life, a long desired change came to the little household, and with a new joy he welcomed his child. With what hope and happiness he accepted the new promise, those who knew him well cannot forget; but the happiness was all too short. "The little spirit only fluttered for a while on the threshold of its prison-house, and unconscious of captivity took flight forever." Writing to a near friend at the time, Hubbard says, "God bless you for the interest you took in my boy. This is all I can say; for I cannot write of him." Nor will I undertake to speak of his grief. Four years later, Mrs. Hubbard's suffering life terminated; and her husband was left alone, with only the remembrance of a home.

As a friend I knew Hubbard well, and can bear witness to the loyalty and gentleness of his nature. With a gayety never bordering on excess, a sympathy never exhausted, a kindly tact never forgotten, he was a companion such as we rarely meet. Of his help and encouragement to me personally, I have already spoken; and since I have read the memorials entrusted to my care, I see that what he did for me he did for many others, each according to his need.

During the last few years of our colleague's life, there seems to have been some modification, or at least exaltation, of the views and sentiments which, perhaps more than any others, tend to make each one of us what we are—I mean our sense of personal relation to the Deity. That high principle and religious fervor which through his life had been a lamp to his feet, showing itself in love to God and man, burnt during these later years with a yet brighter flame. Perhaps, indeed, it may to some of us seem for a moment to have dazzled his vision, and made the shadows which must darken every thoughtful mind seem blacker than those ordained by the hand of a loving Father. In reading these last memorials, we cannot but grieve that his pure and gentle spirit should have passed through those hours of struggle which, to our vision at least, he seemed to need so little. But it is not for us to scan too closely the sacred privacy of these emotions. Let us turn rather to their results.

He was long connected with the religious society of Rev. Dr. Gurley, in Washington; and his letters to his mother show the reliance which he placed upon this excellent man, and the eagerness with which he sought to know and do his Master's will. He became an elder of the church, and not many months before his death, Superintendent of the Sunday Schools of the Presbyterian denomination in the city. In the affections and lives of his associates and pupils, we find the best tribute to the ability and fidelity with which he discharged these duties.

Among the writings of these later months are various treatises on religious and theological subjects, and critical comparisons and reconciliations of various portions of the Old and New Testaments; to all of which he brought the same power of unwearying research that characterized his scientific labors. He attempted the mastery of the Hebrew language, and labored zealously to fit himself for a more critical study of the Bible. Indeed so earnest was his religious devotion that we find indications of some vague aspiration, or half-formed plan, of renouncing even his scientific pursuits in order to enter upon the labors of the Christian ministry. To each one is intrusted his peculiar gift; and we who knew Hubbard as a student and minister of science, cannot but feel that his Maker had clearly pointed out the way in which he best might serve Him, by devoting a rare capacity and pure heart to the study and interpretation of His works.

Perhaps, gentlemen, we may regret that, even for a moment, and from the highest possible motives, he was unfaithful to his earliest choice, and swerved from the path where, as we think, he best served God and man. Yet such questions must be decided by every man for himself, with such light as he may attain;

and it may be that these varied experiences and changes of thought were sent him that he might live through the experience of many years during the lapse of a few, and might learn as many as possible of the lessons of this life during the time allotted him. But can we do otherwise than honor a creed which blossoms in such deeds as crowded the last years of Hubbard's life. His was no bigot's zeal. It led him among the poor, the sick, and the afflicted. It sent him to the hospitals, where he daily spent his hours of official leisure with the soldiers, giving each the needful word of good cheer, or bringing delicacies and comforts to them so far as his own opportunities or those of his friends permitted. It inspired him with a true loyalty to his country, and endowed him with that spirit of self-sacrifice which shone in every action. "The number of letters that he wrote for wounded soldiers," says a friend in writing of him, "was almost incredible. He frequently devoted whole afternoons to this one object. I wonder how many of the soldiers knew whose bright face it was that was so pleasant to them."

With all these self-imposed duties added to his daily and nightly routine of work, who can wonder that his health, always so uncertain, became each month still more impaired; and that when the last summons came it was so quickly answered?

Professor Hubbard left Washington for the last time on the 30th July, 1863. For a few days previous he had been particularly unwell, owing to severe exposure in a sudden shower. But he had looked forward with peculiar pleasure to a meeting of his college classmates in celebration of the twentieth anniversary of their graduation; and he managed to pursue his original plan, and reached New Haven in time for the meeting. But the delicate instrument had been too much shattered to recover its tone, and its music was to be heard no longer. He suffered severely on the journey, and on being assisted into the well-remembered house where his mother was awaiting him, had only strength to say, "O, how good it is to be at home." His mother pressed forward to meet him, and he added those words, which to our ears seem so full of pathos: "Mother, I am worn out."

And so indeed it proved. To the physician who was instantly summoned, he only said: "Doctor, help me to a little strength to meet my class to-morrow night, and then I will give up." But even this gratification was denied him and the affectionate greeting that he sent his classmates was almost his last earthly utterance. Gradually, but surely, he sank away; but who could have wished for him a happier dismissal? Soothed by familiar voices and pleasant images, tended as in his infancy by his mother, surrounded by loving faces, the worn-out man may have felt himself a weary child again; and with a childlike confidence he went to rest, on Sunday morning, August 16—waking, we may be sure, to exclaim once more, "How good it is to be at home." A day or two afterwards his mortal part was laid in the quiet cemetery near us, where, two years before, that very week, he had seen his father laid.

"Sleep sweetly, tender heart, in peace;
Sleep, holy spirit, blessed soul,
While the stars burn, the moons increase,
And the great ages onward roll.

"Sleep till the end, true soul and sweet,
Nothing comes to thee new or strange;
Sleep, full of rest from head to feet;
Lie still, dry dust, secure of change."

Here we leave him. But, gentlemen of the National Academy, let not the name of the first who left our ranks be soon forgotten. Others of those ranks may have emblazoned their names more conspicuously, their memory may be yet more secure of perpetuity, in the annals of science. But none of our number can claim to have surpassed him in those qualities which make the highest glory of a man; and well will it be for us if our names can be inscribed near his, on the highest of records.

If our National Academy is to fulfil its loftiest mission, and achieve a work commensurate with our hope and faith, let us emulate the spirit of him whom we have first been called upon to mourn—the spirit of disinterestedness, of patriotism, and of highest purpose.

MEMOIR

OF

JOSEPH GILBERT TOTTEN.

1788–1864.

BY

J. G. BARNARD.

READ AT THE WASHINGTON SESSION, JAN. 6, 1866.

BIOGRAPHICAL MEMOIR OF JOSEPH GILBERT TOTTEN.

MR. PRESIDENT AND GENTLEMEN OF THE ACADEMY:—

In conformity with a clause of the Constitution of this Academy, and in obedience to your instructions, I am here to render the tribute of a formal biographical notice in commemoration of one who was numbered among our most venerable and most honored associates. If, in the language of one of our body, on a previous and similar occasion, "it is no unreasonable assumption that public benefit and individual incentives may be derived from the history of any man whose scientific services have rendered him worthy of admittance to your number," that assumption must have a peculiar force when it applies to one who has "finished his course," and has filled a life, protracted beyond the usual term, with scientific labors of no ordinary variety and magnitude.

It is but little more than two years since we first met for the great and important work of organizing this National Academy, and with us—of our number, if not personally present—were "both the gray-headed and very aged men." But, alas! these, like autumnal leaves, are rapidly falling away, and already the places of a Totten, a Hitchcock, and a Silliman know them no more, save in the records of their lives and deeds, and in the grateful memories of their associates. What a trio of names, glorious in the annals of science, is this! Well may they be incentives to us, who yet remain to strive that we may worthily replace them, and establish for this Academy a reputation for usefulness and science which their honored bearers have acquired for themselves.

Although there may be many among us more capable than myself of doing justice to the memory of our departed colleague, I feel grateful that the lot has fallen to me. Placed under his command on my first entrance into the military service—almost in my boyhood—my relations with him, both personal and professional, have ever since been continuous and intimate. Under obligations to him of no ordinary nature, I could not do otherwise than regard him with reverence and affection. If I fail, therefore, it shall not be because my heart is unmoved, nor because I am insensible to the magnitude of my task.

JOSEPH GILBERT TOTTEN was born in New Haven, Connecticut, on the 23d of August, 1788. His grandfather, Joseph Totten, came from England before the war of the Revolution, and engaged in mercantile pursuits in New York. Attached to the cause of the mother country, he left that city, after the acknowledgment of our independence, for Annapolis, Nova Scotia. It would appear that his two sons remained in this country, since one of them, Peter G. Totten, married in 1787 Grace Mansfield of New Haven, a very beautiful woman, who died a few years after her marriage, leaving two children; the subject of this memoir and a daughter, Susan Maria, who married Colonel Beatty, an English officer, and who is still living, a widow, in London. After the death of Mrs. Totten, which occurred when her infant son was but three years old, the father, having been appointed United States Consul at Santa Cruz, West Indies, took up his future abode on that island, leaving his son under the care of his maternal uncle, Jared Mansfield, a graduate of Yale College, 1777, and a learned mathematician. The boy continued to be a member of Mr. Mansfield's family until the latter removed to West Point, having been appointed Captain of Engineers and a teacher in the United States Military Academy, then just organized by act of Congress of 1802. Young Totten's first teacher was Mr. Levi Hubbard, brother to the Rector (at that time) of Trinity Church, New Haven; afterwards his education was carried on under the personal superintendence of his uncle. Of the period of his school-boy life we have some glimpses, through the recollections of an old friend and schoolmate, Mr. Ralph Ingersoll of New Haven, who speaks of him as a bright, noble youth, of fine mind, fond of study, and always at the head of his compeers, gentlemanly in his deportment, and greatly beloved.

Young Totten went to West Point with the family of his uncle in 1802. He was soon after appointed a cadet. He remained at West Point one term, that of 1803, and perhaps part of that of 1804. He was promoted to a second lieutenancy in the corps of Engineers, July 1, 1805.

The venerable General J. G. Swift, recently deceased, his brother engineer officer and life-long friend, describes him at West Point as "a flaxen-headed boy of fourteen years of age, a good scholar, and to me a most interesting companion."

Captain Mansfield, having been appointed Surveyor-General of Ohio and the Western Territories, November 4, 1803, induced his nephew to accompany him to the West as an assistant on that first systematic survey of any of the new States of the Union. Here that faculty which so distinguished him through life, of keen observation of whatever was most interesting connected with or incidentally brought under his notice by his professional pursuits, displayed itself at this early age in a noteworthy manner. The vestiges of an earlier race than the red man, which have since been made the subject of the researches of a Squier and a Davis, of a Lapham and of a Haven, and to which, during recent times, fresh attention has been directed by the developments of the high antiquity of the human race in Europe as shown by similar relics over the surface of that country and by the lacustrine remains in Switzerland, attracted his notice and were made the subjects of survey. Although these investigations were not published, they are, I believe, the first we have record of; those of Caleb Atwater, who is called by Squier and Davis "the pioneer in this department," not having been published until 1819. Full descriptions and measurements of several of these mounds, particularly that of Circleville, were made and sent to his friend, J. G. Swift. To most youths of his age those remains of structures, built

> "while yet the Greek
> Was hewing the Pentelicus to forms
> Of symmetry, and rearing on its site
> The glittering Parthenon,"

would have been passed over with vague curiosity or listless indifference. Not so with young Totten. Although not able, perhaps, to perceive all the ethnological importance which has since been attached to them, he could yet appreciate them as objects of high interest, as vestiges of the races which had inhabited the country, and give his time to their examination and measurement.

During the two years which he passed in the office of his uncle at Ludlow's Station, near Cincinnati, he was a companion of several young men who subsequently became conspicuous, among whom were Nicholas Longworth, Samuel Perry, Daniel Duke, Thomas Pierce, and Peyton Symmes, all of whom are now dead. His tastes, however, led him back to the army (from which he had resigned shortly after his promotion), and, February 23, 1808, he was reappointed a Second Lieutenant of Engineers, his commission bearing the same date as that of his subsequent friend, brother engineer officer, and professional associate, Sylvanus Thayer, of national fame as for so many years Superintendent of the Military Academy, and as the officer to whom is mainly due its present high grade among the military and scientific institutions of the world. Lieutenant Totten commenced his career as a military engineer under Colonel Jonathan Williams, the first chief of the corps, and was engaged on the construction of Castles Williams and Clinton, New York harbor.

At the commencement of the war with England Lieutenant Totten was assigned to duty as Chief Engineer of the army under Brigadier-General Van Rensselaer, in the campaign of 1812, on the Niagara frontier, and in that capacity took a conspicuous part in the battle of Queenstown. He was subsequently Chief Engineer of the army under the command of Major-General Dearborn, in the campaign of 1813, and of the army under Major-General Izard and Brigadier-General Macomb, in the campaign of 1814, on Lake Champlain. Having been promoted to a captaincy in 1812, he was in June, 1813, brevetted Major, for "meritorious services," and September 11, 1814, Lieutenant-Colonel, for "gallant conduct at the battle of Plattsburg;" his efficient services as an engineer in the defensive arrangements of that field having contributed powerfully to the successful issue.

The termination of the war may be considered as the close of one period in the life and services of General Totten, and the commencement of another; or rather it may be said, that the events of which we have traced a faint outline were but the preparation and training of his mind for the real work of his life. Reared under the eyes and guardianship of a relative distinguished for his mathematical attainments, receiving as extensive a military and scientific education as West Point at that early day could give, called by his position in Surveyor-General Mansfield's office, not only to exercise the science which the duties involved, but to take extended views of our country as to the interconnection of its parts, and their relations to commerce or war, then practically taught the duties of a military engineer in what concerns the defence of harbors, and finally carried through the ordeal of actual war in the campaigns of armies in the field, he was now prepared for the great work of his life; the fortification of our seaboard frontier. When I call this the great work of his life, I am not unaware that it is but a *part* of that work; still the most important part, and one to which his other labors may be considered incidental.

A brief reference to the condition and progress of sea-coast defence at that period is here appropriate. Previous to the Revolution, our seaport towns had not grown into large cities, nor were there great naval establishments or military depots to invite the enterprises of an enemy. During that contest, the harbors of Boston, New York, Philadelphia, Charleston, etc., had been, to a certain extent, "fortified" against naval attack, by slight earthen batteries, or in some few cases by small and (as we would now call them) insignificant earthen forts. A work of palmetto logs and sand on Sullivan's Island, Charleston harbor, mounting but 30 guns, decisively repulsed, early in the Revolutionary war, the attack of the British fleet under Sir Peter Parker, consisting of two frigates and six sloops of war, carrying about 270 guns, destroying four of the smaller vessels, and inflicting a loss of 205 in killed and wounded (eleven times as many per gun employed against them as the English lost at Trafalgar); thus decisively demonstrating the value of fortifications, and the superiority of land batteries to ships. But with an immense sea-coast line and sparse population, it was impossible to hold our seaports against the great naval power of the mother country, and the war of the Revolution was mainly a contest of land forces. After the attainment of our independence, the importance of fortifying our harbors impressed itself on the mind of General Washington, and the political agitations which grew out of the French revolution, and which threatened to involve the new-born power of the West, prompted early action in this direction. In that day war, though a science, had not grown into one which makes tributary to it all other sciences, as it has since done. Fortification, indeed, had reached a high degree of perfection, but the elaborate treatises on that subject scarcely touched the subject of harbor defence, so little art was apparently supposed to be involved in throwing up batteries to defend the entrances of ports. The art of a Vauban and Cormontaigne was little concerned in the war from which we had just emerged, and the circumstances were too dissimilar, the theatre too large and too thinly populated, the armies engaged too small, to afford to the precepts of a Lloyd or a Templehoff much apparent applicability. While the war developed generals of unquestionable ability in the spheres in which they acted, it seemed to be conceded; that, for military science, and especially for the art of fortification, we must look to Europe. Hence we find so many of the early harbor defences of our principal seaport towns to have been built under the direction of foreign officers who had found employment among us, and who did not always possess the knowledge of the art to which they laid claim.

The importance of a Military Academy for the training of officers for the military service, and especially for the engineers and artillery, had been acknowledged even from the very outset of the struggle for independence. We find even the Continental Congress appointing a committee "to prepare and bring in a plan of a Military Academy," and the first Secretary of War, General Knox, in an official report to the President, discusses the subject at much length. The establishment of such an institution is known to have been a favorite object of General Washington, and in his annual message in 1793 he suggests the inquiry, "whether a material feature in the improvement" of the system of military defence "ought not to afford an opportunity for the study of those branches of the art which can scarcely ever be attained by practice alone;" and in 1796 he states that "the desirableness of this institution had constantly increased with every new view he had taken of the subject."

An act of Congress of 1794 had provided for a Corps of Artillerists and Engineers, to consist of four battalions, to each of which eight Cadets were to be attached, and made it the duty of the Secretary of War to procure books, instruments, and apparatus for the benefit of said corps; and in 1798 Congress authorized the raising of an additional regiment, increased the number of Cadets to fifty-six, and empowered the President to appoint four teachers of the arts and sciences necessary to the efficiency of this "Corps." Of the four teachers, none were appointed prior to January, 1801, at which time Mr. George Barron was appointed teacher of Mathematics, and the institution, "which was nothing more than a mathematical school for the few Cadets then in the service," was nominally established.

It was soon discovered that the regiment of Artillerists and Engineers could not combine with effect the two duties assigned to its members, and a law was therefore framed separating them into two corps, and declaring that the Corps of Engineers should be stationed at West Point, New York, and should constitute a Military Academy. This act of March 16, 1802, which is the organic law of the Corps of Engineers and of the Military Academy, provided for the appointment of a certain number of officers and Cadets[1] (not to exceed twenty in all), and declared that "the principal Engineer, or in his absence, the next in rank, shall have the superintendence of the Military Academy, under the direction of the President of the United States."

It is not my purpose here to follow further the history of that institution; I have alluded to its initiation as a step taken to provide for an acknowledged want of the period—an institution for teaching the military sciences to young men entering the army, and for creating a competent *Corps of Engineers.* It was soon found, however, that the duties of Engineer officers were inconsistent with their remaining at West Point, and themselves constituting "a Military Academy." Most of them were soon called to duties along the seaboard, in constructing our fortifications, while, as the wants of the service and of the Academy have been more clearly seen, the number of Cadets has been increased, to supply not only the Engineers and Artillery, but officers of all arms of the service, and the various professorships and departments of instruction now existing have been established.

As the duties of the Corps became more and more extensive, its chief, though charged with the administration of its affairs, could not be constantly present at the Academy, and it ultimately became apparent that the immediate superintendency of such an institution was incompatible with his proper functions. In 1817,

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[1] Besides ten Cadets of Engineers, forty Cadets "of Artillery" were authorized by this law; making fifty Cadets in all.

an officer selected from the corps (Brevet-Major Sylvanus Thayer, to whom allusion has already been made) was appointed permanent Superintendent of the Academy, and made subject only to the orders of the President of the United States.

Major (afterwards Colonel) Jonathan Williams, a near relative of Dr. Franklin, whom he accompanied, as secretary, to France, where he studied the military sciences, and made himself acquainted with the standard works on fortification, was the first Chief Engineer of the United States under the law of 1802. He was an officer of decided merit, much beloved by his subordinates, and is justly styled the father of the Corps of Engineers and of the Military Academy.

While exercising his superintendence of the Academy, he devoted himself personally to the fortification of New York harbor, and most of the forts which constitute the inner line of defence of that harbor—Fort Columbus, Castles Williams and Clinton (Castle Garden), and a work similar to the last named, located two or three miles higher up the river (Fort Gansevoort)—were planned by him, and built under his immediate supervision.

Castle Williams was the first "casemated" battery erected in this country (built in 1807–10), and was planned after the system of Montalembert, with which, as we have seen, Colonel Williams had made himself acquainted in France. This and other works of Colonel Williams, though they have been superficially and ignorantly criticized, were really meritorious and do not suffer by comparison with European structures of the same or even much more recent dates.

The indications of an approaching war with England, and the obvious inadequacy of existing fortifications, had led to renewed exertions, and prompted the works just mentioned and others at all our seaports, so that when the war broke out there was not a town of any magnitude upon the coast not provided with one or more batteries. But most of the works so thrown up, before the subject had been studied and systematized, as a whole, were defective in design, small, weak, and being built, for present economy, of cheap material and workmanship, very perishable. In the main, however, they answered their purpose—more, perhaps, through an undue respect for them on the part of our foe than through their intrinsic strength. It was not till after the close of the war with England that a permanent system of coast defence was entered upon by our government. Indeed, without the experience of that war it is doubtful whether a measure, always so unpopular, and generally so little understood as a national system of fortifications, could have gained the support of Congress, and of the people. A "Board of Engineers" was constituted in 1816, with instructions to make examinations of the sea-coast, and to prepare plans for defensive works, subject to the revision of the Chief Engineer and the sanction of the Secretary of War.

Up to this period the Military Academy had maintained a sort of embryo existence, without definite form or a prescribed system. The annual term of study lasted from April to November, all the intermediate months being vacation No fixed number of terms was necessary to graduation, nor was it prescribed what should be studied. Some Cadets remained but a single term before being commissioned; others, several years. Although this period produced officers who afterwards became highly distinguished in engineering (as well as in other branches of military art), it is not surprising that the government yet entertained the common notion that only in Europe, and especially in France, could high military science be found; nor that, in undertaking so vast and costly a work as the fortification of our sea-coast, distrust should have been felt in the unaided abilities of our own engineer officers. A distinguished French engineer, General Simon Bernard, was invited to this country, and as "Assistant" in the Corps of Engineers (an office created for the purpose by Congress), made a member of the board which, as first constituted, November 16, 1816, consisted of himself as President, Colonel William McRee, and Lieutenant-Colonel J. G. Totten. In 1817, Colonel Totten was relieved, and appears to have been stationed at Rouse's Point, Lake Champlain, in charge of fortifications at that place, and the board to have been composed of Brigadier-General J. G. Swift, Chief Engineer, Brigadier-General Bernard and Colonel McRee; but Colonel Totten was again made a member in 1819, and (both General Swift and Colonel McRee having resigned) the permanent board came to consist of Bernard and Totten alone, and the labor of working out the fundamental principles of the system, and of elaborating the projects of defence for the great seaports, thus devolved mainly upon these two officers, though naval officers of rank and experience were associated with them whenever their examinations included positions for dock-yards, naval depots, or other objects which concerned the naval service.

Though the advent of a foreign officer, and his assignment to this duty, under the anomalous designation of "Assistant" in the Corps of Engineers, naturally caused some feeling, yet it can scarcely be doubted that the influence of the proceeding was beneficial. If in Swift, McRee, Totten, Thayer, and many others, were found high engineering abilities and acquirements, it is no less true that professional association with such a man as Bernard was calculated to stimulate to higher attainments and more zealous exertion. The spirit of emulation alone would induce our own officers to prove to the country that they were not inferior to others. To high military and scientific acquirements and great experience in his professional duties, General Bernard united to the qualities of an amiable and accomplished gentleman the tact to adapt himself to his peculiar position without wounding the pride of those with whom he was thus associated. The prestige of his name aided powerfully in sustaining, with the administration and with Congress, the measures which the board found necessary to recommend, and in establishing firmly, as a part of our national policy, the system of sea-coast defence by fortifications. In recounting the origin and growth of the system, it is but just to give that name an honorable mention.

By the Board of Engineers of which I have been speaking a series of reports was drawn up, which, mostly from the pen of our departed associate, form his best memorial, and exhibit in a masterly manner the principles of sea-coast and harbor defence, and their application to our own country In a paper of this kind it will not be out of place to give some idea, at least, of the arguments and views contained in these documents. An elaborate report of 1826, from which I quote, gives a general *résumé* of the principles which have guided the labors of the board, and of the results arrived at.

"The means of defence for the seaboard of the United States, constituting a system, may be classed as follows: First, a navy; second, fortifications; third, interior communications by land and water; and fourth, a regular army and well-organized militia.

"*The navy* must be provided with suitable establishments for construction and repair, stations, harbors of rendezvous, and ports of refuge, all secured by fortifications defended by regular troops and militia, and supplied with men and materials by the lines of intercommunication. Being the only species of offensive force compatible with our domestic institutions, it will then be prepared to act the great part which its early achievements have promised, and to which its high destiny will lead.

"*Fortifications* must close all important harbors against an enemy, and secure them to our military and commercial marine; second, must deprive an enemy of all strong positions where, protected by naval superiority, he might fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm; third, must cover the great cities from attack; fourth, must prevent as far as practicable the great avenues of interior navigation from being blockaded at their entrances into the ocean; fifth, must cover the coastwise and interior navigation by closing the harbors and the several inlets from the sea which intersect the lines of communication, and thereby further aid the navy in protecting the navigation of the country; and sixth, must protect the great naval establishments.

"*Interior communications* will conduct with certainty the necessary supplies of all sorts to the stations, harbors of refuge, and rendezvous and the establishments for construction and repair, for the use both of the fortifications and the navy; will greatly facilitate and expedite the concentration of military force and the transfer of troops from one point to another; insure to these also unfailing supplies of every description, and will preserve unimpaired the interchange of domestic commerce even during periods of the most active external warfare.

"*The army and militia,* together with the marine, constitute the vital principle of the system.

"From this sketch it is apparent that our system of defence is composed of elements whose numerous reciprocal relations with each other and with the whole constitute its excellence; one element is scarcely more dependent than the whole system is on any one. Withdraw the navy, and the defence becomes merely passive; withdraw interior communications from the system, and the navy must cease in a measure to be active for want of supplies, and the fortifications can offer but a feeble resistance for want of timely reinforcements; withdraw fortifications, and there only remains a scattered and naked navy."

The relation of the navy to fortifications is one of those subjects not always well appreciated, and hence the cause of mischievous notions and much misrepresentation. No pains are spared in these reports to make this subject clearly understood. After the quotation just given, Colonel Totten remarks:—

"It is necessary to observe, in the first place, that the relation of fortifications to the navy in a defensive system is that of a sheltering, succoring power, while the relation of the latter to the former is that of an active and powerful auxiliary; and that the latter ceases to be efficient as a member of the system the moment it becomes passive, and should in no case (we allude to the navy proper) be relied on as a substitute for fortifications. This position may be easily established.

"If our navy be inferior to that of the enemy, it can afford, of course, unaided by fortifications, but a feeble resistance, single ships being assailed by whole fleets; if it be equal, or superior, having numerous points along an extended frontier to protect, and being unable to concentrate, because ignorant of the selected point of attack, every point must be simultaneously guarded: our separate squadrons may therefore be captured in detail by the concentrated fleet of the attacking power. If we attempt to concentrate under an idea that a favorite object of the enemy is foreseen, he will not fail to push his forces upon the places thus left without protection. This mode of defence is liable to the further objections of being exposed to fatal disasters, although not engaged with an enemy, and of leaving the issue of conflict often to be determined by accident, in spite of all the efforts of courage and skill. If it were attempted to improve upon this mode by adding temporary batteries and field works, it would be found that besides being weak and inadequate from their nature, the most suitable positions for these works must often be neglected, under a necessary condition of the plan, that the ships themselves be defended; otherwise they must either take no part in the contest, or be destroyed by the superior adversary."

It is hardly to be expected that a system affording so much room for discussion, and by its importance inviting it, should, especially in this country, escape adverse judgment. Military and naval men, congressmen, and even cabinet officers have assailed it, called in question the principles on which it is based, or denied the judiciousness of their application. The forms and sources of assault have been varied, but there has been really no great difference in the substance, of which, perhaps, as good an expression as any may be found in these dogmas, forming the pith of a criticism from no less a source than the Secretary of War, Mr. Cass, approved by the President, General Jackson :—

"1st. That for the defence of the coast the chief reliance should be on the Navy.

"2d. That in preference to fortifications, floating batteries should be introduced wherever they can be used.

"3d. That we are not in danger of large expeditions, and consequently,

"4th. That the system of the Board of Engineers comprises works which are unnecessarily large for the purposes which they have to fulfil."

Owing to these strictures, the House of Representatives, by resolutions of April 9, 1840, called upon the War Department for a report of a full and connected system of national defence. The duty was committed by the Secretary of War to a board of officers of the army and navy, among whom was Colonel Totten, and by whom the report was drawn up. It was entirely approved by the Secretary of War, Mr. Poinsett, and is universally admitted to be one of the most able and comprehensive expositions of the whole subject of sea-coast defence extant, and a complete refutation of the objections made to our existing systems. The discussion of the first and principal proposition—that of defence by the Navy—is so interesting and instructive, that, though long, I venture to quote it:—

"The opinion that the navy is the true defence of the country is so acceptable and popular, and is sustained by such high authority, that it demands a careful examination.

"Before going into this examination, we will premise that by the term 'navy' is here meant, we suppose, line-of-battle ships, frigates, smaller sailing vessels and armed steamships, omitting vessels constructed for local uses merely, such as floating batteries.

"For the purpose of first considering this proposition in its simplest terms, we will begin by supposing the nation to possess but a single seaport, and that this is to be defended by a fleet alone.

"By remaining constantly within this port, our fleet would be certain of meeting the enemy, should he assail it. But if inferior to the enemy, there would be no reason to look for a successful defence; and as there would be no escape for the defeated vessels, the presence of the fleet, instead of averting the issue, would only render it the more calamitous.

"Should our fleet be equal to the enemy's, the defence might be complete, and it probably would be so. Still, hazard, some of the many mishaps liable to attend contests of this nature, might decide against us; and in that event, the consequences would be even more disastrous than on the preceding supposition. In this case the chances of victory to the two parties would be equal, but the consequences very unequal. It might be the enemy's fate to lose his whole fleet, but he could lose nothing more; while we in a similar attempt would lose not only the whole fleet, but also the object that the fleet was designed to protect.

"If superior to the enemy, the defence of the port would in all respects be complete. But instead of making an attack, the enemy would in such case, employ himself in cutting up our commerce on the ocean; and nothing could be done to protect this commerce without leaving the port in a condition to be successfully assailed.

"In either of the above cases, the fleet might await the enemy in front of the harbor, instead of lying within. But no advantage is apparent from such arrangement, and there would be superadded the risk of being injured by tempests, and thereby being disqualified for the duty of defence, or of being driven off the coast by gales of wind; thus for a time removing all opposition.

"In the same cases, also, especially when equal or superior to the enemy, our fleet, depending on having correct and timely notice as to the position and state of preparation of the enemy's forces, might think proper to meet him at the outlet of his own port, or intercept him on his way, instead of awaiting him, within or off our own harbor. Here it must be noticed that the enemy, like ourselves, is supposed to possess a single harbor only; but having protected it by other means, that his navy is disposable for offensive operations. If it were attempted thus to shut him within his own port, he, in any case but that of decided inferiority, would not hesitate to come out and risk a battle; because if defeated, he could retire under shelter of his defences to refit, and if successful, he could proceed with a small portion of his force —even a single vessel would suffice—to the capture of our port now defenceless, while, with the remainder, he would follow up his advantage over our defeated vessels, not failing to pursue into their harbor, should they return thither.

"Actual superiority on our part would keep the enemy from volunteering a battle; but it would be indispensable that the superiority be steadily maintained, and that the superior fleet be constantly present. If driven off by tempests, or absent from any other cause, the blockaded fleet would escape, when it would be necessary for our fleet to fly back to the defence of its own port. Experience abundantly proves, moreover, that it is in vain to attempt to shut a hostile squadron in port for any length of time. It seems, then, that whether we defend by remaining at home, or by shutting the enemy's fleet within his own harbor, actual superiority in vessels is indispensable to the security of our own port.

"With this superiority, the defence will be complete, provided our fleet remains within its harbor. But then, all the commerce of the country upon the ocean must be left to its fate; and no attempt can be made to react offensively against the foe, unless we can control the chances of finding the enemy's fleet within his port, and the still more uncertain chance of keeping him there; the escape of a single vessel being sufficient to cause the loss of our harbor. Let us next see what will be the state of the question on the supposition of numerous important ports on either side, instead of a single one; relying on our part still exclusively on a navy.

"In order to examine this question, we will suppose our adversary to be fortified in all his harbors, and possessed of available naval means, equal to our own. This is certainly a fair supposition; because what is assumed as regards his harbors is true of all maritime nations, except the United States; and as regards naval means, it is elevating our own strength considerably above its present measure, and above that it is likely to attain for years.

"Being thus relatively situated, the first difference that strikes us is, that the enemy, believing all his ports to be safe without the presence of his vessels, sets himself at once about making our seas and shores the theatre of operations, while we are left without choice in the matter; for if he thinks proper to come, and we are not present, he attains his object without resistance.

"The next difference is, that while the enemy (saving only the opposition of Providence) is certain to fall upon the single point, or the many points he may have selected, there will exist no previous indications of his particular choice, and, consequently, no reason for preparing our defence on one point rather than another; so that the chances of not being present and ready on his arrival are directly in proportion to the number of our ports, that is to say, the greater the number of ports, the greater the number of chances that he will meet no opposition whatever.

"Another difference is, that the enemy can choose the mode of warfare as well as the plan of operations, leaving as little option to us in the one case as in the other. It will be necessary for us to act, in the first instance, on the supposition that an assault will be made with his entire fleet; because, should we act otherwise, his coming in that array would involve both fleet and coast in inevitable defeat and ruin. Being in this state of concentration, then, should the enemy have any apprehensions about the result of a general engagement, should he be unwilling to put anything at hazard, or should he, for any other reason, prefer acting by detachments, he can, on approaching the coast, disperse his force into small squadrons and single ships, and make simultaneous attacks on numerous points. These enterprises would be speedily consummated, because, as the single point occupied by our fleet would be avoided, all the detachments would be unopposed; and after a few hours devoted to burning shipping, or public establishments, and taking in spoil, the several expeditions would leave the coast for some convenient rendezvous, whence they might return, either in fleet or in detachments, to visit other portions with the scourge.

"Is it insisted that our fleet might, notwithstanding, be so arranged as to meet these enterprises?

"As it cannot be denied that the enemy may select his point of attack out of the whole extent of coast, where is the prescience that can indicate the spot? And if it cannot be foretold, how is that ubiquity to be imparted that shall always place our fleet in the path of the advancing foe? Suppose we attempt to cover the coast by cruising in front of it, shall we sweep its whole length ?—a distance scarcely less than that which the enemy must traverse in passing from his coast to ours. Must the Gulf of Mexico be swept as well as the Atlantic? or shall we give up the Gulf to the enemy? Shall we cover the Southern cities, or give them up also? We must unquestionably do one of two things; either relinquish a great extent of coast, confining our cruisers to a small portion only, or include so much that the chances of intercepting an enemy would seem to be out of the question."

The report then goes on to discuss the uses for defensive purposes of gunboats, floating batteries and steam batteries, as distinguished from the navy proper. Admitting their usefulness, and even, in some cases, their necessity, it argues, with great force, that they are not a substitute for, and cannot supersede fortifications, and it sums up its argument concerning naval defence with the following broad propositions, to which it challenges opposition:—

"1st. If the sea-coast is to be defended by naval means exclusively, the defensive force at each point deemed worthy of protection must be at least equal *in power* to the attacking force.

"2d. As from the nature of the case there can be no reason for expecting an attack on one of these points rather than on another, and no time for transferring our state of preparation from one to another after an attack has been declared, each one of them must have assigned to it the requisite means; and,

"3d. Consequently this system demands a power in the defence as many times greater than that in the attack as there are points to be covered.

"There has been but one practice among nations as to the defence of ports and harbors, and that has been a resort to fortifications. All the experience that history exhibits is on one side only; it is the opposition of forts or other works, comprehended by the term fortification, to attack by vessels, and although history affords some instances wherein this defence has not availed, we see that the resort is still the same. No nation omits covering the exposed points upon her seaboard with fortifications, nor hesitates in confiding in them."

The most prominent cases of such successful attacks, viz.: Copenhagen, Algiers, San Juan de Ulloa, etc., are then described and discussed, to show that the deductions drawn from them are erroneous, or that they are not cases in point, or that the disastrous result has been owing to the neglected condition, imperfect armament or unskilful and inadequate defence of the forts.

The report, of which I have given some of the main points, may be said to have silenced opposition to our system of fortifications for the next ten years; but, in a form modified by the alleged changes in the condition of the country, increase of population, construction of railroads, etc., it again found expression in a resolution of Congress in 1851; and the Secretary of War, to enable himself to respond, called upon numerous distinguished army and navy officers for an expression of their opinions. The following questions were addressed to several of the principal Engineer officers, among whom the Chief of Corps, General Totten:—

"1st. How far the invention and extension of railroads have superseded or diminished the necessity of fortifications on the seaboard?

"2d. In what manner and to what extent the navigation of the ocean by steam, and particularly the application of steam to vessels of war, and recent improvements in artillery, and other military inventions and discoveries, affect this question?

"3d. How far vessels of war, steam batteries, ordinary merchant ships and steamers, and other temporary expedients, can be relied upon as a substitute for permanent fortifications for the defence of our seaports?

"4th. How far the increase of population on the nothern frontier and of the mercantile marine on the northern lakes obviates or diminishes the necessity of continuing the system of fortifications on these lakes?"

General Totten's response to these critical interrogations is, as usual with him when this great subject has to be dealt with, full and exhaustive. The following pithy paragraphs exhibit his views on the influence of railroads.

"Suppose a hostile fleet to lie in front of the city of New York, —which nothing would prevent, if the channels of approach were not fortified—in what way could the 100,000 or 200,000 new men poured into the city and environs by railroads, although armed with muskets and field-pieces, aid the half-million of people already there? It seems to me very clear that these additional forces would, like the population of the city, be utterly powerless in the way of resistance, with any means at their command; and, if resistance were attempted by the city, would but serve to swell the list of casualties, unless they should at once retreat beyond the range of fire. If the enemy's expedition were intended, according to the second supposed mode of attack, for invasion, or occupation for some time, of a portion of the country, then, in many places, this resource of railroads would be of value, because then the duty of defence would fall upon the army and militia of the country; and these communications would swell their numbers.

"But of all circumstances of danger to the coast, this chance of an attempt by an enemy to land and march any distance into a populous district is least to be regarded, whether there be or be not such speedy mode of receiving reinforcements, and our system of fortifications has little to do with any such danger. In preparing against maritime assaults, the security of the points to be covered is considered to be greatly augmented whenever the defence can be so arranged as to oblige an enemy to land at some distance; for the reason that opportunity is thereby allowed, in the only possible way, for the spirit and enterprise of the people to come into play.

"Instead of being designed to prevent a landing upon any part of the coast, as many seem to suppose, and some allege in proof of extravagant views on the part of the system of defence, the system often leaves this landing as an open alternative to the enemy, and aims so to cover the really inportant and dangerous points as to necessitate a distant landing and a march towards the object through the people. It is because the expedition would easily accomplish its object without landing, and without allowing the population to partake in the defence, that the fortifications are resorted to. For instance, without Fort Delaware, or some other fort low down on Delaware Bay, an enemy could place his fleet of steamers in front of Philadelphia by the time his appearance on the coast had been well announced throughout the city. And in spite of all New Jersey, Delaware, and lower Pennsylvania, he could levy his contributions, and burn the navy-yard and shipping, and be away, in a few hours. But being obliged, by the fort above mentioned, to land full forty miles below the city, the resistance to his march may be safely left to the courage and patriotism that will find ample time to array themselves in opposition."

Concerning the application of steam to vessels of war he says:—

"The application of steam to vessels of war acts upon the question of sea-coast defence both beneficially and injuriously. It acts injuriously in several ways; but chiefly, first, by the suddenness and surprise with which vessels may fall upon their object, and pass from one object to another, in spite of distance, climate, and season; and, secondly, by their ability to navigate shallow waters.

"The first property, by which squadrons may run into our harbors, outstripping all warnings of their approach, affords no chance for impromptu preparations; accordingly, whatever our preparations are to be, they should precede the war. It seems past all belief that a nation having in commission—as France and England always have—a large number of war steamers, ready for distant service in twenty-four hours, receiving their orders by telegraph, capable of uniting in squadrons, and in two or three days at most speeding on their several paths to fall upon undefended ports—it is not to be expected, I say, that they should delay such enterprises until temporary resorts could be got ready to receive them. And yet there are those who insist that we should leave defensive measures to a state of war, that we should let the day supply the need!

"Inadequate as all such measures must prove, there would not be time to arrange even these. By the second property, due to their light draft of water, these vessels will oblige the defence to be extended in some form to passages or channels or shoals that were before adequately guarded by their shallowness. The bars at the mouth of the Mississippi formerly excluded all but small vessels of war, and the strong current of the river made the ascent of sailing vessels exceedingly uncertain and tedious. Now these bars and currents are impediments no longer. And all the armed steamers of Great Britain and France might be formed in array in face of the city of New Orleans before a rumor of their approach had been heard.

"Had the English expedition of 1814, attended by a squadron of armed steamers, arrived at the mouth of the Mississippi, a few transports might have been taken in tow, and in a few hours the whole army would have been before the city. Or twelve or fifteen such steamers could have carried the whole army up in half a day, without the delay of transports. Will it be contended that the attack in that form would have been repulsed with the means then in General Jackson's hands? Would the landing, or even the presence on board these steamships, of the British troops have been necessary to burn the city or put it under contribution? Is there anything now, but the existence of forts on the river, to prevent the success of such an attack by fifteen or twenty steamers of war, allured there by the vastly increased magnitude of the spoil?"[1]

While the enemy's means of attack are thus enhanced by the use of war-steamers, General Totten contends that they cannot be relied upon, as a substitute for fortifications, for defence.

"I do not assert," he says, "that armed vessels would not be useful in coast defence. Such an idea would be absurd. I shall even have occasion to show a necessity for this kind of force, in certain exceptional cases. It is the general proposition, viz., that armed vessels, and not fortifications, are the proper defences for our vulnerable points—a proposition the more dangerous, because seemingly in such accordance with the well-tried prowess and heroic achievements of the navy—that we have now to controvert.

"Boston, New York, Philadelphia, Baltimore, Charleston, and New Orleans are, we will suppose, to be guarded, not by forts, but by these vessels, on the occurrence of a war with a nation possessing large naval means. We know that it is no effort for such nations to despatch a fleet of twenty line-of-battle ships and frigates, or an equal number of war steamers, or even the combined mass—both fleets in one.

. . . . . .

"What, then, shall we do at the above-named ports severally? Each is justly felt to be an object worthy of an enemy's efforts, and each would be culpable in sending elsewhere any part of the force required for its own defence. Each, therefore, maintains a naval force equal, at least, to that the enemy is judged to be able to send promptly against it. Omitting any provision for other places scarcely less important, what is the result? It is, that we

[1] The experience of the Rebellion has proved the truth of General Totten's words. The moment the *forts* were passed, the city of New Orleans was, notwithstanding the land forces under Lovell, at Commodore Farragut's mercy. I have alluded elsewhere to the failure of the forts.

maintain within the harbors of, or at the entrance to, these places, chained down to this passive defence, a force at least six times as large as that of the enemy.

"He does not hesitate to leave his port, because it will be protected in his absence by its fortifications, which also afford him a sure refuge on his return. He sails about the ocean, depredating upon our commerce with his privateers and small cruisers, putting our small places to ransom, and in other ways following up appropriate duties; all which is accomplished without risk, because our fleet, although of enormous magnitude, must cling to ports which have no other defence than that afforded by their presence. They cannot combine against him singly, for they cannot know where he is; and must not, moreover, abandon the object which they were expressly provided to guard.

"It would really seem that there could not be a more impolitic, inefficient, and dangerous system, as there could not certainly be a more expensive one."

I have thus extensively quoted from the reports of General Totten, because they are themselves the best expressions of the life labors and services of the subject of our memoir, and because I think they treat of matters which should be, in an eminent degree, interesting to the members of this National Academy, and which, moreover, should demand its attention.

To preserve the continuity of my subject, I have followed these reports down to a late date. It is necessary now to revert to an earlier period. It has already been observed, that as soon as the original Board of Engineers had sufficiently matured the general system of defence, and completed plans for the works first required, its members applied themselves to the duty of construction. In 1828, General (then Colonel) Totten took charge of the construction of Fort Adams, Newport harbor, and continued on this duty, making his residence in the town of Newport, until December, 1838, the date of his appointment as Chief of the Corps of Engineers. This work, the second in magnitude of the fortifications of the United States, is one of the best monuments of genius as a military engineer. From its peculiar relations to the land defence, it called for the application of most of those rules of art, and many of those special arrangements which form the themes of treatises upon "fortification," and which, generally, have but a very limited application to works of harbor defence. In these respects it has no parallel with us, and in the treatment of the case and happy adaptation of means to the end, Colonel Totten exhibited a mastery of all the details of the art, which proves his technical skill and minute knowledge to be fully equal to the power of broad generalization I have already endeavored to illustrate. But Colonel Totten found here yet another field for professional usefulness—another tract to explore. The art of the civil engineer (I use the phrase in its application to mere *construction*, whether it be of a military or civil work) was yet in its infancy in this country. Our resources in building materials were almost unknown, their qualities and adaptabilities to different purposes of construction undeveloped. Thus far the matter had excited little attention; the building material, whether brick or stone, lime or timber, nearest at hand was indiscriminately used, and its aggregation left much to the skill of the mechanic. In commencing constructions on so great a scale, it was of the first importance that the work should be both durable and economical; a result only to be attained by the most careful selection of materials, and the most skilful manipulation. Besides, our forts called for arrangements unknown in other branches of building—arrangements for which the execution and the most suitable materials had to be studied out *ab initio*, since on many of these points there were neither experience nor extant rules to guide.

In the years 1830 and 1831 a series of experiments was instituted by Colonel Totten at Fort Adams, on the expansion and contraction of building stone by natural changes of temperature, and the effects of these variations on the cements employed to secure the joints of stone copings. An account of them was prepared under his direction by Lieutenant (now Professor) W. H. C. Bartlett, a member of this Academy, and published in the American Journal of Science for July, 1832. The methods employed were at once simple and ingenious, and the result was such as to leave no doubt that in this climate the joints of copings formed of stone of four or five feet in length will always be insecure, no matter what description of cement may be employed to close them.

This result is one of great practical importance. Previously to the experimental examination of the subject by Colonel Totten, the walls of our most expensive works of masonry were protected by copings cemented at their joints; and while the failure of the cement was constantly noticed, the cause of the failure was not understood. The experiments showed that the changes of longitudinal dimensions of granite coping-stones, five feet only in length, under the extreme temperatures to which they were exposed at Newport, would be sufficient to pulverize the hardest cement between them, or to leave cracks in it thicker than common pasteboard. With marble as a material, these destructive effects are considerably increased, and with sandstone, nearly doubled.

About the same time, Colonel Totten caused some experiments to be made to ascertain the relative stiffness and strength of the following kinds of timber, viz., White Pine (*Pinus strobus*), Spruce (*Abies nigra*), and Southern Pine (*Pinus australis*), also called Long-leaved Pine.

These experiments, made by his assistant, Lieutenant T. S. Brown, of the Corps of Engineers, were published in the American Journal of Science and Art, and afterwards, having been revised by the author, in the Journal of the Franklin Institute, a note being added, the calculations extended, and practical inferences drawn therefrom. This memoir and additions are found in Vol. VII., new series, Journal of the Franklin Institute, 1831. Lieutenant Brown's account concludes with the following remarks:—

"In Tredgold's carpentry, and other similar works, may be found the constant numbers (a) and (c) for nearly all the kinds of wood useful in the arts; but besides that the numbers are in many instances calculated from insufficient experiments, most of the specimens used in the trials were of European growth, and of course the results obtained are inapplicable to American timber, though bearing the same name. It is much to be desired that numerous and accurate experiments be made in this country by those having the requisite zeal and opportunities; our architects will then know with certainty the qualities of the different kinds of woods they are using, and instead of working at hazard and in the dark, as they now too often do, they will be guided by the sure light of practical science to certain and definite results. If these experiments contribute ever so little to the attainment of so important a result, the object of their publication will be fully accomplished."

A subject of such vital importance in the art of construction as the composition of mortars could not fail to invite, or rather compel, the researches of Colonel Totten. No species of masonry is subject to such severe deteriorating influences as the walls and arches of fortifications, especially in our climate; so severe, indeed, that they almost drive the engineer to despair. Next only to the importance of having the building stones or bricks of a suitable character, is that of uniting them by a strong and durable mortar. Few persons whose attention has not been called to the subject conceive its magnitude, the variety of materials it embraces, and the laborious investigations to which it has given rise. Colonel Totten commenced his researches at an early date, and continued them actively during the whole period of his connection with Fort Adams.

His work on "Hydraulic and Common Mortars" was published in 1838 by the Franklin Institute of Philadelphia. It contains, besides original experiments and observations on mortars, hydraulic cements, and concretes, translations of essays by Treussart, Pitot, and Courtois, the best French writers on the same subject, and constitutes to this day an authority relied on by American engineers. Colonel Totten's experiments extend over the period from 1825 to 1838; they are especially valuable for the variety of limes and cements, and the tests of different modes of slaking the lime, mixing the mortars, and preparing the cements and concretes. The mortars were tested, after periods ranging from five months to four years and five months, for tenacity, by the force required to separate two bricks joined together by means of them, and for hardness by the weight which they would support, applied over a small circular area. The experiments on concretes or factitious stones are equally comprehensive, being directed to the composition and consistency of the cement whether best used as a stiff mortar or a semi-fluid grout; to the effect of additions of common lime and sand or rounded pebbles and gravel, and to ascertaining the proportion of each that would be used to the best advantage. The results developed by these investigations are of the greatest value, and having been applied in the construction of the fort, have now had the test of many years' experience.

It would be almost impossible to enumerate the various objects of Colonel Totten's researches while at Newport. There is scarce a subject connected with the art or science of the engineer, civil or military, which did not engage his attention, and of which he has not left some record. The thickness of sustaining walls, the thrust of arches, among the more important, and the composition of stuccoes, of paints, lackers, washes for stone or brick work, among the less so, may here be mentioned.

Perhaps no period of his life is so interesting and so affectionately remembered by his professional associates. Indeed, a large proportion of the young officers of the corps of those days passed a portion of their time under his command, and acquired their first professional experience in the performance of duties under his eye and direction. The disposition to cultivate science, physical and natural, led him to original researches, while his influence stimulated and led to improvement the educated young men who from time to time came into his military family. Fond of exercise, bodily and mental, he sought in natural history, as in geology, mineralogy, and conchology, objects for the long walks and drives conducive to health, while the arrangement of the specimens, their care and classification, and the study of the habits of the animals which occupied the shells, gave scope to his wonderful powers of observation. Instead of finding his young officers a trouble, he was fond of their companionship, suggesting modes and objects of experiment, and encouraging them to do so likewise, thus cultivating originality of thought. His laboratory was at their service, and his companionship and example at their disposal. After a day's labor he retired to this laboratory, glad to have with him such of the young companions of the day as desired to join him. The honored President of this Academy can recollect, year after year, the computations, under Colonel Totten's direction, of the thickness of revetments, the analysis of minerals collected in the field, classifications of shells gathered in days' walks on the sea-shore, discussions of the curious structure of geological specimens in the neighborhood of Newport, and of the curious mineralogical specimens of the upper portion of Rhode Island, which he encouraged them to find. So upon the fort itself, the various researches which I described were marked out for successive experimenting, with a generosity to his assistants which almost persuaded them that they were original with them. The determination of the measures used in laying out the fort and the practical apparatus employed in the measurements, received his careful study. The practical character of these works impressed itself upon the minds of the young officers, and furnished the fitting complement to the theoretical training received at West Point.

Not least pleasant among the memories of this period of Colonel Totten's life, to those who had the good fortune to be associated with him, is the recollection of the social enjoyments of his house. Married in 1816 to Catlyna Pearson, of Albany, he was surrounded by a young family, among whom his happiest moments were spent, and to whom he was everything that such a relation can imply. None could be happier in his social intercourse. Genial and eminently hospitable, he cultivated as a duty those smaller amenities of society by which the cares of life are lightened, and its joys augmented. His house was the home of his friends, and was seldom without some one of them. Though dignified and courteously reserved in his intercourse with the external world, few more highly enjoyed real humor, or could with more true *bonhommie* give themselves up to the gayety of the moment. In his relations to his young officers he was kind and affable, encouraging freedom of expression, and inviting inquiry in everything that related to professional matters, while there was always that in his manner which inspired the most profound respect and forbade undue levity of conduct in his presence.

Before quitting the scene of so important a portion of Colonel Totten's official labors, it is proper to remark that, in addition to the duties of his particular charge, he as a member, and for the last six years President of the board of engineers, was engaged in the planning of the new works for which Congress from time to time made the necessary appropriations.[1] To this duty he usually devoted the winter months, during which all construction on Fort Adams was suspended. In the execution of his designs he was usually assisted by young officers of the

[1] By the Regulations, the local engineer officer, upon whom the construction of the proposed work was to devolve, was *ex officio* a member of the board. This brought together during the winter months engineer officers from various parts of the country—from the shores of the Gulf, from the seaboards of North and South Carolina and Georgia, as well as from nearer points, and added not a little to the charm of the professional and social life of the young engineer officers at Newport.

corps, who found therein a practical application of the theoretical knowledge acquired at West Point instructive and useful.

The works of harbor improvement on the seaboard and on the lakes were likewise under the control and direction of the Engineer Bureau; and Colonel Totten, though not directly engaged therein, was not infrequently called on to inspect and advise concerning them. Most of these, and especially those of the Lake shores, affording curious and interesting problems in this branch of civil engineering, and his reports and notes on these subjects, yet extant, are additional proofs of the wide range of his professional knowledge and of his powers of accurate observation and of skilful deduction from the phenomena of nature.

Colonel Totten was appointed Colonel of the Corps of Engineers and Chief Engineer, Dec. 7, 1838. At this time the construction of Fort Adams was so far advanced towards completion as to need no longer his personal supervision, and the city of Washington became thenceforth his home and the seat of his official duties. Identified as we have seen with the origin and growth of the great system of sea-coast defence of the United States, it was eminently proper that he should become the head of that bureau of the War Department to which its execution was committed, and no one could be more eminently fitted for that important station.

At the date of his appointment the system of coast defence had been for about twenty years in progress of construction, and during that period most of those ports and harbors of the United States deemed most important to ourselves or most assailable by a naval foe had been, at least, partially fortified. At many such points, indeed, no new work had been as yet constructed, owing to the existence of forts or batteries more or less adequate built before or during the war of 1812. These works, where possible, were absorbed into the new system with some repairs and alterations. Among such points may be mentioned the harbors of Portland, Portsmouth, New London, Philadelphia, Baltimore, and Charleston. New and powerful works had, however, been built or far advanced to completion, for the defence ot Boston, Newport, New York, Hampton Roads, the Savannah River, Pensacola, Mobile, and New Orleans. But the strictures on the system, to which we have before made reference, proceeding from such an authority as the Secretary of War and sanctioned by the President, had not failed to shake the confidence of Congress and of the people. For several years the annual appropriations had been wholly denied or made so inadequately that the work had languished and at some points had been wholly suspended. But however much opposition may grow up in time of profound peace, no sooner is there a probability of seeing a foe at our doors than all eyes are turned to these protecting works, and the most urgent demands are made that our seaport towns shall be speedily put "in a state of defence." Such an impulse was given by the Maine boundary and McLeod questions, soon after the advent of Colonel Totten to the Chief Engineership. In fulfilling the urgent duty which thus devolved upon him, he did not content himself with the mere issuing of orders from his office at Washington. He made it his business to inspect personally the works, and in less than two years, besides the enormous office labor he found necessary to attend to on the first assumption of charge of the bureau, he had visited every fort and battery on the sea-coast of the United States. His inspections were not superficial and hasty; they were most thorough and searching. His investigations embraced, at the same time, the general scope and purpose of the work, its adaptability to its great objects, and the minutest detail in its construction. It was now that the country derived the full benefit of his indefatigable researches while at Newport.

I have already alluded to the lack of knowledge and experience in this country of the art of construction, especially in its applications to the peculiarities of fortification. To supply this lack was a great end of Colonel Totten's labors at Fort Adams. At few other points did the locality or circumstances of the construction render practicable such researches. This remark will apply particularly to the works on the Gulf of Mexico. The regions bordering the Gulf were, at the close of the war of 1812, but recent acquisitions to the territory of the United States. Sparsely populated and isolated from the rest of the Union as (before the application of steam to the navigation of the Mississippi) they were, they would be defended, if defended at all, only by the aid of fortifications. The fact that New Orleans had been almost wrenched from our grasp, and the impression then everywhere felt that if it had been captured it would not have been relinquished, stimulated the government to secure the possession of this important place and of other strategic points on the Gulf by immediate fortification. Accordingly designs for works—mostly prepared by General Bernard—were among the first labors of the Board of Engineers, and the forts on the river and lake approaches to New Orleans, at the entrances to Mobile Bay and Pensacola harbor, were almost simultaneously commenced. Around New Orleans especially the Engineers had to contend with formidable difficulties. The deadly climate, the treacherous soil, on which no art could build a structure so massive as a fortification that should not sink one or more feet, warping and dislocating the walls and arches, the difficulties of procuring the services of mechanics and laborers, the want of building materials, etc., all combined to make construction exceedingly difficult, to forbid any of its niceties, and to hinder all research or experiment. Some of these works had been entirely finished at the period we have arrived at, others nearly so, and left to "settle" before the weight of the earthen parapets was added.

Considering all these unfavorable circumstances, these works had been built in a manner creditable to the energy and skill of the engineers; but a few years' neglect, aided by a damp and tropical climate, had given many of them an appearance which, to the superficial observer, promised anything but efficiency. Indeed, it was a popular belief in New Orleans at this time that Fort Jackson on the Mississippi had sunk so much that its guns could not be brought to bear on the river,—a belief doubtless due to the unnecessarily high *levees* by which it had been surrounded to protect its site from inundation, and to the rapid growth of vegetation on and about the fort. Such was the condition of this work when Colonel Totten first visited it in 1841, and the author of this paper, who had but recently taken charge of it, has yet a vivid recollection of the thorough inspections of this and other works, the tedious voyages in open boats through the intricate "bayou" navigation about New Orleans, in company with his chief, as well as the copious and most minute instructions which he received. Destitute of American experience on such points, the designer had followed European precedents, or the constructing engineer had been left to his own devices as to much that relates to the interior arrangements. The wood-work of magazines, inadequately ventilated, had rotted and fallen in ruins; the covering of the bomb-proof casemates, imperfectly understood, had failed to exclude water, which percolated through the piers and arches or gathered in muddy pools on the floors. The work to be done to bring the forts to speedy efficiency was vast; embrasures and floors of casemates were to be raised to compensate the settlement the works had undergone; earth to be removed from the arches, in order to repair or renew the roofing; magazines and quarters to be refitted, and all this before a gun could be mounted in a proper manner. On all these points Colonel Totten was rich in the experience of his long researches, and ready at once to give the proper directions. Following his detailed instructions, the works speedily reached such a condition of efficiency as to permit the mounting and service of their guns.[1]

What the writer here relates from his own experience at New Orleans serves but to illustrate the indefatigable labors and personal agency of Colonel Totten at this period, along the whole seaboard of the United States, in bringing all its ports and harbors into a defensible condition. Nor should I confine these attributes to any particular period. During the whole time of his Chief Engineership he continued the same laborious supervision. Generally, once in about every two years, he inspected every fort of the United States, and scarcely was the local engineer officer more thoroughly familiar with each detail of his own particular works than was the Chief Engineer with those of all under charge of the Engineer Bureau. Besides attending to the routine duties of his office at Washington, he found time to design plans for new works, as well as for alterations or enlargement of old ones. An admirable draughtsman, executing his work with a delicacy and finish that defied competition on the part of his subordinates, he would be usually found, if visited at his office, engaged at his drawing-table. Indeed, if he had a fault as Chief Engineer, it was the habit of doing everything himself. It was contemplated by the Regulations that all plans of fortifications should be made by a Board of Engineers, and General Totten, in one of his reports,

[1] When Forts Jackson and Philip on the Mississippi were attacked by the fleets of Commanders Farragut and Porter, they were not provided with the armaments intended for them, and the garrisons were demoralized by a long bombardment. It is not in place to discuss this subject here.

alludes to the fact that this has *not* always been the case in these words: "In rare cases it has happened that plans have been made under the particular direction of the Chief Engineer, owing to the difficulty, at moments, of drawing the widely dispersed members of the board from their individual trusts." It may be said too, in justice to him, that when he assumed the control of the bureau, it was almost indispensable to take much upon himself, in the direction of the repairs and prosecution of many of the works, owing to the great pressure thrown upon the corps by the circumstances of the period and the want of a sufficient number of experienced officers.

The excitement produced by the anticipation of war with England was followed by an actual war with a weak neighbor—a war inaugurated by the same influences which, in a more potent form, produced the Rebellion, or rather of which the Rebellion was but the legitimate and natural sequel. Called on by General Scott, who reposed in his professional skill the most unbounded confidence, Colonel Totten assumed, in 1847, the immediate control of the engineering operations of the army destined to invade the Mexican capital, directing in this capacity the siege of Veru Cruz. For his successful services he was brevetted a Brigadier-General, March 29, 1847, "for gallant and meritorious conduct at the siege of Vera Cruz." Having thus successfully accomplished the special task for which he had been selected, he left the army and resumed his station at Washington.

In addition to the onerous duties of his office, involving, besides the labors described, the Inspectorship and Supervision of the Military Academy, his position and high reputation subjected him to calls for incidental labors, by the government, by the States, or by municipal bodies. A few months prior to his appointment as Chief Engineer, 1838, he was, at the invitation of the Secretary of the Navy, ordered to visit the Navy-Yard at Pensacola, and to prepare plans for dry-docks, wharves, sea-walls, and other improvements. Save a wretched failure in the shape of a wharf, the place—a navy-yard in name—had been, up to this period, destitute of everything that characterizes such an establishment, except an imposing row of officers' quarters, and some few storehouses. A board of naval officers had been convened two years previously to consider the wants of the yard, and had recommended an extensive system of improvements, involving, among other things, no less than four dry-docks. Such constructions, reaching thirty or more feet below the level of low water in the loose sand of the bay shores, were difficult, demanding all the resources of the engineer, and it was on account of General Totten's eminent abilities and high authority in such matters that the Navy Department had recourse to his services. He made a report on the manner of construction, with plans which, if I mistake not, have been a guide in the subsequent operations. Unfortunately, to this day no permanent dry-dock exists, a floating wooden one having, through some influence, been substituted, at enormous expense, for the intended masonry structure.[1]

The Legislature of the State of New York having, March 30, 1855, passed "An Act for the appointment of a commission for the preservation of the harbor of New York from encroachments, and to prevent obstructions to the necessary navigation thereof," the commission so appointed invited and obtained the co-operation, as an "advisory council," of General Totten, Professor Bache, and Commander Davis, U. S. Navy. The nature of the services thus renderd is best understood by reference to the reports of the Commissioners themselves.

"The distinguished reputation of General Totten, Professor Bache, and Commander Davis for scientific attainments, their diversified experience in the construction of hydraulic works, and long observation of the influence of tidal currents in the formation and removal of shoals, indicated them as the best qualified to assist the Commissioners in the discharge of their duties, while their high personal character precluded the possibility of their advice being affected by other than the single purpose of arriving at a just decision on the questions submitted to them;" and again, after a particular allusion to the services of Professor

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[1] The "questionable shape" and suspicious object of this novel craft—set afloat and towed out into the bay by the Rebels in 1861—caused anxious surmises on the part of Colonel Brown and the gallant garrison of Fort Pickens, reminding us of the famous "Battle of the Kegs" of the Revolution. The probable object was to sink it in the channel to prevent the entrance of our gunboats. But Colonel Brown's interference prevented the accomplishment of the design. It was abandoned by the rebels, and set fire to by Colonel Brown's orders.

Bache: "It is the gratifying duty of the Commissioners to present to the notice of the Legislature the important services which have been gatuitously rendered to the State by General Joseph G. Totten, Chief Engineer of the United States Army, and Commander Charles H. Davis, of the United States Navy, who, with Professor Bache, formed the advisory council of the Commissioners. Animated by the single desire of preserving the port of New York in all its usefulness, they brought to the consideration of the subjects referred to them the diversified experience of many years spent in the examination and improvement of harbors. The several reports they have made on the exterior lines, on the improvement of Hell Gate, and on the preservation of Gowannus Bay, are profound dissertations on the forces and actions of currents, and, while they evince, in some degree, the extent of the labors of those gentlemen, they demonstrate how just is the public estimate of their scientific attainments."

Following the example of New York, Massachusetts soon organized a similar commission for the port and harbor of Boston, on which the same gentlemen were invited to serve, receiving similar testimonials of the high value of their services.

Of the many scientific men of the country who were associated with him in such duties (of whom most usually was our eminent President), none exhibited greater zeal and assiduity, few took a more prominent and useful part. The resolutions of the Light House Board, on the occasion of his decease, which are appended to this memoir, would be, with slight modifications, applicable in reference to all his connections of a similar nature. Inflexible in his integrity, uncompromising in his notions of duty, and watchful to the highest degree for all the interests of the government in all that concerned his charge, it is not strange that the shameless Floyd soon found him an obstacle to his peculiar operations. He was virtually banished from his office, or at least relieved from his duties, which he did not resume until Floyd left the War Department. He took this opportunity—perhaps the very first and only release during his lifetime from the unceasing demand of duty—to visit Europe in company with Mrs. Totten, travelling through France, Italy, Germany, and England. Endued with those keen perceptions and that harmonious adjustment of faculties which render the mind susceptible to the beautiful, whether in nature or art, he was, in the true sense of the term, an artist. For music, for painting, for sculpture, he had a high relish and a most accurate and discriminating judgment. By such a one the treasures of art and antiquity of Europe can only be adequately appreciated and enjoyed, as we know they were appreciated and enjoyed by General Totten. He did not fail, however, to take the opportunity to examine, as far as he was able, the fortifications of Europe, of the character and peculiarities of which, however, he had little to learn. On his return he was sent by Floyd to the Pacific coast, with directions to inspect the fortifications in construction, and to report on the defensive requirements of that region. This duty and the report thereon he executed in his usual thorough and exhaustive manner. It furnished him with the opportunity to acquire the same personal knowledge of all that concerned the seaboard defence of our newly acquired territories on the Pacific which he already possessed, beyond any other man, in reference to the Atlantic and Gulf coasts.

In the year 1851 General Totten inaugurated and continued through the years 1852, 1853, 1854, and 1855 a series of experiments at West Point, "on the effects of firing with heavy ordnance from casemate embrasures," and also "on the effects of firing against the same embrasures with various kinds of missiles." It will be interesting and conducive to a better understanding of the objects and results of these experiments to say a few words as to the origin and meaning of the term "casemate," and to give an account of General Totten's previous labors in connection with the "casemate embrasure." The word is from the Spanish *casa-mata* (a compound, most likely, of *casa*, house, and *matar*, to kill; though it is said also to mean a low or hidden house; but the etymology is not settled), and seems to have been used to signify a countermine as well as a concealed place, arranged in connection with a fortification, for containing and using a piece of artillery. According to Bardin[1] it appears to have been applied to the double or triple tier of uncovered gun platforms used by the early Italian and German engineers for flanking the ditch, as well as to vaulted galleries along the scarp wall. The term finally came to mean, in fortifi-

[1] Dictionnaire de l'Armée de Terre, etc.

cation, any vaulted room under the earthwork of the rampart or glacis, whether intended for service of guns or for quarters of troops or for containing stores. A *gun casemate* is such a vault abutting against the scarp or counterscarp wall through which an "embrasure" is pierced to permit the discharge of the gun; and in the naval service the term has been adopted to signify the part of an iron-clad vessel containing the guns, and which is, for that reason, especially protected by the iron-plating. Hence the essential notion of the word seems to involve one or more of the attributes of concealment, shelter, and destructive purpose.

The use of the casemate, in some of its forms, for flanking purposes goes back to Albert Durer and San Micheli, in the early part of the sixteenth century, and it was resorted to by Vauban in his second and third systems, of which the tower-bastions are casemated throughout. But it was reserved for the Marquis de Montalembert, in the latter part of the eighteenth century, to give it an extraordinary development, and to make the casemate the essential element of a system of fortification. This "most intrepid of authors upon fortification" (as he is styled by Chasseloup) boldly attempted to apply to his art the same principles by which Napolean won his victories—the concentration of superior forces upon the decisive points. In his projects we find upon all parts where there must be a decisive contest of artillery an extraordinary concentration of guns, amounting in some cases to ten times those of the attacking batteries, the construction of which it is intended to prevent, or which shall be promptly overpowered, if constructed. This concentration he effected, and could only effect, by the use of casemates, upon which, numerous and well constructed, he bases all the strength of his fortifications.

No author on this art has displayed greater genius or a greater affluence of resources, and no author has given occasion for so much acrimonious discussion. Rejected by the French, the principles of Montalembert have been made the basis of the modern German, or "Polygonal" system.

For sea-coast fortifications the casemates of Montalembert had a singular applicability, and he has the merit at least of being the first writer who has seen in this branch of the art a subject of particular treatment, and who had given special designs for forts and batteries "for the defence of ports."

In no warlike structure was there so great a concentration of artillery as in a ship of war, such as it was fifty or even twenty years ago. And as there is no limit to the number of ships which may be brought to bear upon a shore battery save that of the range of artillery and the area of navigable water, it is easy to see to what overwhelming hostile fire such a work may be subjected. On the other hand, it frequently happens that the site otherwise most advantageous for a battery is low and contracted, rendering any accumulation of guns impracticable, if mounted on an ordinary rampart, and exposing the unprotected gunners to the fire of the sharpshooters with which the enemy's topmasts are filled.[1]

It is no small merit of Montalembert to have devised a method of mounting guns which should meet this case. Notwithstanding that the French Corps of Engineers rejected the system in its intended application, and disclaimed, as an engineer, its author, it nevertheless constructed, in 1786, for the defence of the roadstead and harbor of Cherbourg, forts which are in reality almost copied from his designs.[2] Following the example of the French, other European nations have adopted, for the defence of their seaports, works of the same character, of which the forts of Cronstadt and Sebastopol, once made familiar to us in their outward appearance, by the Pictorials, are recent specimens, and, as we have already seen, Colonel Williams introduced them into our country in 1807, by the construction of Castles Williams and Clinton, and Fort Gansevoort, New York harbor.

An objection urged against casemates, and a grave one, since it is aimed at one of their most important attributes, is that the embrasures of masonry are dangerous to the gunners, from their outward flaring surfaces reflecting into the interior the enemy's missiles. Montalembert was well aware of this objection, calling

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[1] The topmasts of many of the vessels of Commodore Farragut's fleet in the attack on Fort Jackson and St. Philip contained boat-*howitzers*, destined to fire canister at the gunners of the low batteries of those works.

[2] The celebrated Carnot, then an officer of French engineers, but who adopted the views of Montalembert, writes to him, "You have wrung from your adversaries the admission that well-constructed casemates are a good thing," etc. (ZASTROW, *Histoire de la Fortification.*)

the embrasure, in its ordinary form, a "murderous funnel" (*entonnoir meutrière*), and his sagacity did not fail to prescribe the best remedy by rules intended to reduce to a minimum the external opening. He directed that the throat should be no larger than necessary to receive the muzzle of the gun and to endure the shock of its discharge, that it should not be more than two feet from the exterior surface of the wall, that the cheeks should be parallel to the sides of the sector of fire; and to render practicable these arrangements, he invented the "*affut à aiguille*" (carriage with tongue), which has served as the type of nearly all subsequent casemate gun-carriages. It is strange, that, even while adopting the plans of Montalembert, European engineers should have almost wholly overlooked these maxims, and that it was reserved for our own illustrious engineer to make their application, and in perfecting the casemate and the embrasure, to become a co-worker with Montalembert, by bringing the casemated water battery to its highest degree of perfection.

I now revert to General Totten's labors in this connection, and in reference thereto I quote from his report to the Secretary of War:—

"The first casemated battery was completed in 1808. It has two tiers of guns in casemates, and one in barbette. The exterior openings of the lower embrasures are 4′ 8″ by six feet, giving an area of 28 square feet; and of the second tier, 3′ 8″ by 5 feet, area $18\frac{1}{3}$ square feet, the horizontal traverse of the guns being limited to 44 degrees.

"Within three or four years of the time just mentioned two other casemated batteries were built, each having a single tier of guns in casemates, with exterior openings of 4′ 5″ by 5 feet, area 22 square feet; one with horizontal scope of about 42 degrees, and the other of about 45 degrees.

"In 1815 the author of this report was called on to prepare a project for the defence of an important channel; and having been convinced, while employed as an assistant in the construction of two of the batteries just mentioned, that the principles and the details by which the embrasures and the dependent casemates had thus far been regulated were erroneous and defective, set about a careful study of the conditions to be fulfilled in providing for the heavy guns of that period, mounted on a casemate carriage that had already been approved and adopted. The result was an embrasure, having an exterior opening of 4 feet wide by 2′ 6″ high at the outside line of the cheeks, and three feet high at the key of the covering arch, the throat being 1′ 10″ wide. This provided for all the depression and elevation of the gun that the carriage permitted, and also for a horizontal scope of full 60 degrees. Covered with a lintel instead of an arch, the height of the exterior opening might be a little less than three feet.

"The plan of this embrasure shows that the interior opening is 5′ 6″ wide, and that the plane of the throat is within 2 feet of the outside of the wall, which just at the embrasure is five feet thick.

"A slight modification fitted this embrasure, when applied to flanking or interior defence, to receive at first a carronade of large calibre, and of later years, a howitzer instead. When these latter were liable to be assailed by musketry, the outer cheeks were made *en cremaillière* (notched)—a long-known device.

"It was with timidity and hesitation that the cheeks and this embrasure were placed so near the track of the ball, when fired from the casemate, with the maximum obliquity, and the results of an early trial with experimental embrasures at Fort Monroe gave some sanction to the doubt. The first two under trial were built of lime mortar, and were soon shaken to pieces by the blast of the gun. Another one, however, constructed of bricks laid in cement mortar, sustained without injury several hundred discharges. These last results have been confirmed wherever there has been practice from our embrasures, which, with immaterial differences, have since 1815 been constructed in all our casemated batteries according to the preceding description."

It will be seen from the foregoing quotations how thoroughly General Totten, in adopting the casemated battery, was imbued with the spirit of its illustrious originator. If, as is likely, he was aware of the latter's rules on this subject, he was the first to appreciate their essential importance, and to prove the practicability of their application. It is probable, however, that the close study of the subject, critical observation and keen sagacity which so distinguished him on all occasions, and which taught him to accept nothing as the best which was susceptible of improvement, led him to recognize as "murderous funnels" the embrasures of routine—to create anew the rules of Montalembert, and to make, for the first time, a successful application of them. He reduced the throat to nearly an absolute minimum: he placed it at two feet from the outer face of the wall, diminishing the external openings from eighteen, twenty-two, and twenty-eight, down to about ten square feet, while he increased the sector of fire of the gun from forty-five to sixty degrees; thus adding one third to its field of fire, and consequently to its value.

The embrasures, thus modelled in 1815, remained unchanged until the year 1858, but the casemate continued a subject of study and experiment during most of his life. The perfecting of ventilation, the determination of the dimensions and height of the piers, of the span and rise of the arches, their thickness and manner of covering, so as to obtain perfect drainage and to avoid the injurious effects of frost, etc., were problems of prolonged research and skilful solution, establishing for General Totten the right to be considered the author of the American casemate.

In connection with these researches may be mentioned those also which were directed to the determination of the manner of mounting guns "en barbette."[1] As the dimensions of sea-coast ordnance increased, more and more elaborate structures became necessary for their mounting and management. The planning and construction of the carriages belonged to the Ordnance Bureau, but it was General Totten's task to adapt the platforms and parapets thereto. None but the engineer or artillerist can thoroughly understand the difficulty and complexity of the problems therein involved. To provide a platform which shall support, without the slightest deflexion, the weight, and resist the shock of discharge, while it provides for the training or pointing of the gun—which is so adapted to the parapet as to allow the maximum horizontal sector of fire and to afford the most perfect cover to the gunners consistent with allowing all the depression demanded by the circumstances of the case—such are the conditions to be fulfilled, separately, for each calibre of gun. After years of experience, and after our sea-coast ordnance had attained its highest development prior to the introduction of the rifled gun and fifteen-inch columbiad, General Totten embodied his results in a lithographic sheet exhibiting to the eye of the engineer for

[1] A barbette gun is one which is fired over a parapet.

every kind of gun and for every probable case the particular solution. This single sheet exhibits strikingly the characteristics of the author's mind—the profound study which he brought to bear on every subject, the scrupulous accuracy of his determinations, which neglected no appreciable magnitude, and the thoroughness and generality of his solutions.

When the embrasure of 1815 was designed, ships' armaments contained no gun heavier than a twenty-four or thirty-two pounder. As the calibres increased, it became a matter of doubt whether the five feet thickness of wall immediately about the embrasure was sufficient. At the same time the progress made in the art of forging large masses of iron had suggested that by its use the funnel form of the mouth might be entirely done away with, and the exterior opening reduced to an absolute minimum. Nothing but *experiment* could lead to sound conclusions, and the experiments referred to on a former page were instituted, the principal objects of which were (in General Totten's own language) :—

I. "To ascertain the effects of firing with solid balls, with shells, and with grape and canister, from heavy ordnance at short distances, upon various materials used in the construction of casemate embrasures.

II. "To determine whether these embrasures might have a form that would shut out most of these missiles, and resist for a time the heaviest, without lessening the sector of fire, horizontal and vertical, of the casemate gun.

III. "To determine the degree to which, without injury from the blast of the gun, or lessening its scope of fire, the throat of the embrasure, and also the exterior opening, might be lessened.

IV. "To determine whether all smaller missiles might not be prevented from passing through the throat into the battery ; and whether the smoke of the blast might not also be excluded by simple and easily managed shutters."

Targets were constructed, representing the wall of a fortification pierced with its embrasures. All varieties of materials were employed in the walls, and every suggested method of constructing the embrasure was tried. General Totten's report shows that the minutest detail of construction was directed by himself, and that he personally superintended the experiments. They were carried on at intervals during four successive years, the results of each year suggesting the object of experiment for the next.

It would be out of place here to follow the report through its detailed accounts of the firings, or even to attempt to sum up the conclusions arrived at, referring as they do to such a variety of subjects; but those concerning the thickness of the scarp-wall and the use of wrought-iron may be properly quoted as among the most important.

"The general conclusion from these trials is, that, whether of cement concrete, of bricks, or of hard stones, the portion of the wall at and around each embrasure having the thickness of five feet only should be no larger than is indispensable for the adaptation of the gun and carriage to the embrasure; if restricted to a small area, this thickness will suffice—not otherwise.

"The thickness of five feet will resist a number of these balls, impinging in succession on that space, provided the bond expand promptly above, below, and on each side, into a thickness greater by some two and a half feet or three feet or more. Were the wall no thicker generally than five feet, being reinforced only by piers some fifteen feet apart, it would soon be seriously damaged by battering at short distances."

And in reference to iron it is stated: "First, It may be fairly assumed, that a plate eight inches thick of wrought iron of good quality, kept in place by a backing of three feet of strong masonry, will stop a solid ball from an eight-inch columbiad, fired with ten and a quarter pounds of powder from the distance of two hundred yards. The plate of iron will be deeply indented at the point of impact, the ball carving for itself a smooth bed of the shape and size of one hemisphere, in which it will be found broken into many pieces easily separable, and it will besides be somewhat bent generally. The masonry behind will be much jarred, and, unless strongly bonded, be considerably displaced; moreover, unless the thickness of three feet is well tied into thicker masses immediately adjacent on the sides and above and below, the general damage will be severe.

"Second, This plate will be much the stronger for being in a single mass, and not made up of several thinner plates. The continuity effected by bolts and rivets of the made-up plates is broken even by weak assaults, so that afterwards the stronger, instead of a joint opposition, finds only a succession of feeble resistances.

"Third, A thickness of two inches is ample for shutters designed to stop the largest grape-shot. With this thickness they will be neither perforated nor deformed by anything less than cannon balls or shells. These shutters also, for the reason just given, should be made of a single thickness. The firings show the necessity of concealing entirely, even from the smallest iron missile, their hinges and fastenings.

"Fourth, A wrought-iron plate of half an inch in thickness is adequate to protect the outer margins and the offsets of embrasures from injury by grape or canister shot."

These facts established, the effect of the form and dimensions of the embrasures in carrying in the smaller missiles was investigated; the recorded results will enable us to appreciate the force of Montalembert's expression, "murderous funnels," as even its author could not do.

"Suppose a hundred-gun ship to be placed within good canister range of a casemated battery of about the ship's length and height, to the fifty guns of the ship's broadside there would be opposed about twenty-four guns in two tiers in the battery. The ship would fire each gun once in three minutes, or ten times in half an hour; the fifty guns would therefore make five hundred discharges within that time.

"With one hundred and fifty-six balls in each thirty-two-pound canister (weighing in all thirty-one and a half pounds) there would be thrown seventy-eight thousand balls in thirty minutes. Supposing one-half to miss the fort—which, considering the size of the object, and the short distance, is a large allowance—there would still remain the number of thirty-nine thousand balls to strike a surface of (say) six thousand square feet, that is—

"On each square foot, ... $6\frac{1}{2}$ balls.

"Or within the exterior opening of one of the embrasures of our second target, of which the area is 8, 9 square feet, there would fall, . 58 balls.

"Within the European embrasure above mentioned, having fifty-four square feet of opening,[1] there would be received in half an hour . . 351 balls."

[1] Reference is made to the embrasure of an European work built within the last twenty-five years.

And if the ship carried modern eight-inch guns, and fired canister of musket balls, these figures would be in the three cases fifty-one, four hundred and fifty-three, and two thousand seven hundred and fifty-four. These theoretical conclusions were verified by the experimental firing with grape and canister, and it is thus seen how greatly superior General Totten's embrasure of 1815, which is but little larger than that of the second target, is to the European one, and how thoroughly he had, at that early day, mastered the subject. He had indeed perfected the embrasure as far as it could be done with masonry alone.

But the quantity of small missiles which even that embrasure would receive is dangerously great, and would be much diminished if the funnel form of the mouth could be done away with, and the throat reduced to an absolute minimum. This could be accomplished only by the use of iron, and the conclusions I have just quoted furnish the data necessary to its successful application.

The throat (still placed two feet back from the outer face of the wall) being formed of iron plates, it became practicable to cut away the flaring surfaces of masonry, so as to present others parallel or perpendicular to the face of the wall, and by this change of form to exclude all missiles not directed within the limits of the throat itself. Still more completely to accomplish the object, wrought-iron shutters of two inches thickness (as determined by the experiments) were applied, by which, except at the moments of aiming and firing, the embrasure was entirely closed.

Such is the history of the casemated battery and casemate embrasure in the United States. We have seen that the perfection to which they have been brought is due to General Totten, and to General Totten alone. Nor is it to the experiments which I have been describing, laborious, skilful, and thorough as they were, that we may solely attribute such results. We must look back to the time when, a First Lieutenant of Engineers, he saw and aided in the construction of our first casemated fort, and when he, fully appreciating its merits and recognizing the defects which a disregard and want of appreciation of the illustrious projector's own principles had entailed upon it, set himself to the task of enhancing the one and correcting the other.

The ten years which have elapsed since 1855 have witnessed changes in the character of sea-coast and naval artillery, and an increase in the calibres and weight of their projectiles, which no one at that date would have anticipated; hence some doubt may be entertained whether our casemated masonry works are adequate to contend with iron-clad vessels armed with the modern artillery. This is a question which it remains for experiment or experience to decide. It has, as yet, not been demonstrated that a masonry fort, constructed as our more recent works are, will not, armed with the powerful guns now being introduced, endure the contest quite as long as its iron-clad antagonist can protract it.

In this connection it is due to General Totten to say that he has himself been ever the most strenuous advocate of "big guns," the most urgent instigator of their production. The writer well remembers when, seated with him on the piazza of the officers' quarters at Fort Jackson, our eyes resting on the mighty stream flowing past us, upon the defence of which our thoughts and conversation had been turning, he exclaimed, "We must have a twenty-inch gun." The idea was novel to me at that time, and I exhibited some surprise. He went on to say, that, thoroughly to prevent the passage or attempted passage of an armed steamship, there must be not only danger, but almost a certainty of destruction. "Let us have guns such that (to use his own phrase) 'every shot shall be a bird.'" The invention of armored ships, not then foreseen, has increased the necessity of having such guns as he, on other grounds, so strongly advocated. He expressed the greatest confidence that a gun of the dimensions he named would yet be made and introduced into our batteries, and added the interesting statement, that in his earlier days he had found much difficulty in impressing upon the members of boards on which he had served the necessity of having guns in our harbor defences larger than twenty-four pounders. To the labors and genius of a Rodman we owe the actual invention of the art of constructing fifteen and twenty inch guns; but without the unceasing stimulus of General Totten's known and urged views, it is doubtful whether Rodman's labors would have been called for or sustained.

The preceding pages have been mainly devoted to the illustration of our departed associate's career as an officer and as the Chief Engineer of the United States Before turning our attention to other spheres of his usefulness, it seems fittin to quote from one of his eulogists the following summary of his official characteristics.

"In wielding the influence of his office as Chief Engineer, the prominent traits exhibited by General Totten were strict justice and scrupulous integrity. No sophistry, no blandishments, no arbitrary exercise of superior authority, could turn him in the least from his steadfast adherence to his own sense of duty. Avoiding all useless collisions with his official superiors, showing due respect to their station, he never failed to call their attention to any errors committed by them with respect to the department under his charge; nor did he ever leave them any excuse for wilful wrong-doing by remaining silent; even when he knew that his suggestions would not only be ill-received and of no use, but might be visited by the exercise of those petty vexations which official superiors can employ against those under them who thwart their misdoings.

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"The individual traits of General Totten were strongly marked. Powerfully built, of a constitution of the most vigorous stamp, cool, potent, and persevering, of sound judgment and variety of intellectual capacity, Nature seemed to have endowed him for the profession that he had chosen. His attention to the performance of his professional duties amounted to a devotion.

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"Whilst steadily adhering to what had been well settled by experience, and withstanding the ill-directed efforts of that class of men, of whom some are to be found in all bodies, who seize upon every novelty and press it into the service of their own crude notions, he was far from rejecting well-reasoned projects of improvement, and encouraged, as his own immediate works show, every step towards real progress. Although not belonging to the class of mere inventors, he had that invaluable faculty to one holding a position of so great public responsibility, of detecting the fallacies with which this class too frequently deceive themselves as well as others."

In 1863, under the law uniting into one the two Corps of Engineers and Topographical Engineers, General Totten was advanced to the full grade of Brigadier-General. A few days before his death the Senate unanimously confirmed his nomination by the President to be "Major-General by brevet, for long, faithful, and eminent services." Never were such distinction and such commendation more fitly bestowed.

Giving the precedence in order to duties most intimately connected with his profession, I now turn to General Totten's important labors in establishing and maintaining our present lighthouse system.

The attention of Congress having been called to the pressing necessity for introducing certain reforms, administrative and executive, into the lighthouse system of the United States, that body, after full discussion of the subject, passed an act (approved March 3, 1851) stipulating that from and after that date, in all new lighthouses and all lighthouses requiring illuminating apparatus, the lens or Fresnel system should be adopted.

Another chapter of the same act provided for the appointment of a commission to be composed of two officers of engineers of the army, and such civil officers of high scientific attainments as might be under the orders or at the disposition of the treasury department and a junior officer of the navy as secretary, whose duty it should be to inquire into the condition of the lighthouse establishment of the United States, and to make a general detailed report and programme to guide legislation in extending and improving our present system of construction, illumination, inspection, and superintendence.

The board, as constituted by the President, consisted of Commander W. B. Shubrick, General J. G. Totten, Colonel James Kearney, Captain S. F. Dupont, U. S. N., Professor A. Dallas Bache, Superintendent U. S. Coast Survey, and Thornton A. Jenkins, U. S. N., as secretary.

Its labors were directed first to demonstrating the evils, irregularities, aud abuses which had crept into the lighthouse service under the management of the Fifth Auditor of the Treasury (the late venerable and highly respected Stephen Pleasonton), among which were found to be those arising from defective principles of construction, renovation, and repair of lighthouses, inadequate protection to sites and badly planned and poorly constructed sea-walls. It may readily be understood how the peculiarly practical mind of General Totten, brought to bear upon these and kindred subjects of inquiry, developed and demonstrated the necessity of at once employing proper scientific systems and plans of construction. His assistance in collecting data was found invaluable, and his lucid, clear mind was equally to be trusted in detecting faults and in devising the remedy.

Without entering into a detailed account of the labors of this Board of Inquiry, it is sufficient to state, that the mass of evidence collected by it was so irresistible in proof of existing errors, that Congress, under date of August 31, 1852, passed an act which created a permanent Lighthouse Board, to which were confided all the duties of the establishment. General Totten was appointed to this board, and served as a valued and honored member, with but a short interruption, until his decease. Its early labors were arduous and onerous. A new system was to be founded where before had been none—order should come from chaos, error was to vanish before science, economy to succeed to wastefulness, darkness to give place to light. The task, great as it was, fell upon no shrinking hearts or feeble brains. The work was accomplished; and long before his lamented death General Totten had the satisfaction of witnessing the labors of himself and his associates crowned with full success. The board in its deliberations derived great benefit from his presence and participation, and relied with entire assurance upon the correctness of his judgment upon all subjects concerning which he would express an opinion. He served almost continuously as chairman of the Committee of Finance, and the decisions of that committee owe not a little of their sound wisdom to the searching scrutiny joined to the generous and liberal views of its chairman. He was also a member of the Committee on Engineering, in which department his peculiar merit was most conspicuous. The principal works with which his name is associated and which claim our attention, are the lighthouses on Seven-Foot Knoll, near Baltimore, Md., and on Minot's Ledge, off Cohasset, Mass.

The former is an iron pile structure standing in some ten feet of water. It was erected at a time when the science of iron pile construction was in its infancy, and was one of the first works of the kind undertaken by the board. Hence it was a matter of deep interest and solicitude. It was successfully completed, and the lighthouse stands to-day a signal reward for the thought and labor bestowed upon its conception and construction.

The lighthouse at Minot's Ledge was a work of far greater difficulty, and to its proper location and plan General Totten lent the resources of his great experience and exhaustless knowledge. As his intimate acquaintance with the whole coast of the United States, acquired while acting as a member of the Board of Engineers, and during his annual inspections as Chief Engineer, enabled him, with the aid of the Coast Survey, to indicate with almost unerring certainty the proper location and character of all new lighthouses, so his practical knowledge of construction, in laying the foundation of our sea-coast fortifications and the sea-walls by which the sites of many of them had to be protected, prepared him to grapple with the difficulties of constructing a masonry tower in this exposed situation, and to bring to their solution all the known and tried resources of engineering.

Minot's Ledge is situated about twenty miles southeast of Boston. It is the outer rock of a very dangerous group called the "Cohasset Rocks," lying at the very wayside of navigation to the harbor of Boston. A lighthouse of iron had been erected here a few years previous to the organization of the Lighthouse Board, but it was carried away in a fearful storm which swept along the coast of New England on the 16th of April, 1851.

Not only the commercial interests of the country, but humanity demanded that it should be replaced, and Congress promptly made an appropriation for this purpose, stipulating that the tower should be erected on the outer Minot, and confiding its construction to the Topographical Bureau. This bureau, having publicly advertised, received sixteen distinct proposals to erect the proposed structure, but finally recommended, in view of the difficulties to be overcome, and the fearful fate of its predecessor, that it should be located on one of the inner rocks. In accordance with this recommendation, an act of Congress was passed authorizing the Secretary of the Treasury to "select instead of the outer Minot's Ledge, any more suitable site." Before further action had been taken, the whole subject fell into the hands of the newly created Lighthouse Board. A joint resolution of Congress was then passed (1854) giving to this board the decision as to the location and the mode of construction.

The question of location being thus widely reopened, a committee of the board was sent to make a personal examination of the locality. General Totten was, of course, a member of this committee, and was not long in making up his mind that the outer and not the inner Minot was the proper site. His arguments on this subject proved conclusive with the board. He urged that if the light were placed on any of the inner rocks the desired object would be but partially accomplished, since in a dense fog or thick snow-storm vessels might approach within a few hundred feet, without being able to see it, and thus be lost upon the outer ledge.

When the question of practicability was broached, his professional pride seemed to be roused. He argued that, after what had been done on the coast of England in the erection of the Eddystone lighthouse a century ago, and more recently of the Bell-rock and Skerryvore lights, it would be a humiliating admission that the requisite science and skill were not to be found in this country to erect a similar structure where, as all admitted, one was so much needed.

He carefully studied the accounts of the construction of the Eddystone, Bell-rock, and Skerryvore lighthouses, by Smeaton, Robert Stevenson, and Allan Stevenson, but the fact that the Eddystone was begun at high-water mark, that the ledge of the Bell-rock was extensive and elevated several feet above low-water, and that the Skerryvore presented still less difficulties, while the surveys show that the outer Minot's ledge was very contracted and that the proposed structure must commence even below low-water, did not deter him from advocating and designing a work for this formidable position, more difficult to accomplish than anything which had ever preceded it.

The plans which he prepared were drawn with his usual minuteness of detail. The problem was one peculiarly fascinating to engineers—the uniting into a single mass the several component stones of the structure so that no one can be detached from the rest, that each shall be a bond of connection to those adjacent, that the whole shall be an integral, having a strength ample to defy the most powerful foe to human structure, the fury of the ocean's winds and waves. Though not himself the constructor of the work, yet to have insisted against authoritative adverse opinion on its practicability, to have planned the building and selected the engineer who should rear it, and to have overlooked the work from its commencement to its completion, entitles him, even were this his only work, to recognition among the Smeatons and Stevensons and Brunels, as one of the great engineers of the age.

For the execution, he selected Captain (now Brevet Brigadier-General) Barton S. Alexander, of the Corps of Engineers, an officer whose experience, energy, boldness, and self-reliance eminently fitted him for the task. It is for him to recount the history of the work, to give to the world the interesting narrative of difficulties met and overcome, of patience requited and energy triumphant. General Totten watched its progress with unflagging interest, making frequent visits to the superintending engineer, aiding him with his counsels and encouraging him in his difficulties. He lived to enjoy the proud satisfaction of inspecting the finished structure; and when at last from its towering summit flashed o'er the troubled waters the beacon-light of safety to the tempest-tossed mariner, he might well exclaim, with the Latin poet, though in a nobler sense and in a less boastful spirit: "Exegi monumentum ære perennius."

General (then Colonel) Totten was named in the act of Congress organizing the Smithsonian Institution in 1846 as one of the Regents to whom the business transactions of that celebrated establishment are intrusted. At an early meeting of the Board of Regents he was appointed one of the Executive Committee, and was continued in these offices by repeated election to the time of his death, a period of nearly eighteen years. He evinced a lively interest in the organization of the institution, and after a careful study of the will and character of Smithson, gave his preference to the programme prepared by Professor Henry, which was finally adopted. His advocacy of the plan was the more important since he was well acquainted with the scientific character of James Smithson, and had himself, as we shall see in a subsequent statement, been engaged in a line of research similar to one of those pursued by the founder of this institution.

In the reconstruction of the interior of the main part of the Smithsonian building which had partly been completed in wood, but which had given way, he strongly urged the employment of fire-proof material, to the adoption of which the preservation of the valuable collections of the institution is indebted In the discharge of his duty as one of the Executive Committee, he acted with the same conscientious regard to the sacredness of the trust which characterized all his official labors, and critically examined all the accounts, assured himself as to the proper expenditure of the fund, and advised as to the general policy to be pursued. In him the Secretary ever found a firm supporter, a sympathetic friend, and a judicious adviser. Unostentatious, unselfish, and only desiring to advance whatever cause he might be connected with, he gave the most valuable suggestions as if they were of little moment, and in such a way that they might appear to be deductions from what others had said or done, being more anxious that his suggestions should be properly carried out than that they should be accredited to himself.

As a recreation from the more arduous studies of his profession, he devoted in the early part of his life his spare hours to Natural History, paying much attention to the Mollusca of the Northern coast of the United States; and he was perhaps the first, or at least one of the first to introduce into this country the use of the dredge for the search of these animals, thus not only obtaining many species which would otherwise have escaped attention, and getting fresh and unmutilated specimens of species previously known only from dead imperfect shells, but enabling us to learn something of the habits and associations of the animals—information of much greater scientific value than the discovery of a few new species. His observations and studies in conchology were embodied in an article entitled "Descriptions of some Shells belonging to the Coast of New England," published in the American Journal of Science and Arts for 1834 and 1835, and Dr. A. A. Gould was largely indebted to him for material employed in his "Invertebrata of Massachusetts," many of the species of shells contained in which were first found to inhabit our coast by General Totten; others were new species discovered by him, though described by Dr. Gould, while some nine or ten specimens were not only discovered but described by him. The descriptions of species and remarks evince his powers of observation and critical acumen, and almost all of the forms described have stood the test of subsequent examination, and the validity of their specific distinction been confirmed; although several of them are among the most common shells of the coast, on account of their small size, they had been previously overlooked or neglected, but their insignificance in size did not diminish their interest in the eyes of one who viewed nature in all her manifestations as worthy of contemplation. One of the most beautiful and almost the smallest of the bivalves of our coast, called by him *Venus gemma*, has since been dedicated to him under the name of *Gemma Tottenii* by Mr. William Stimpson.

General Totten collected principally on the shores of New England, and his explorations with the dredge were almost entirely made in the vicinity of Newport, R. I., and of Provincetown, Mass. A list of the shells of Massachusetts was contributed by him to one of the preliminary reports on the Natural History of that State. The principal species described by him are as follows: *Madiola glandula* (now known as *Mytilus decussatus*), *Venus gemma* (*Gemma Tottenii*), *Solemya borealis*, *Bulla oryza*, *Natica immaculata*, *Turbo minutus* (*Kissoa minuta*), *Turritella interrupta* (*Chemnitzia interrupta*), *Acteon trifidus* (*Chemnitzia trifida*), and *Pasithea nigra.* This last-named species he described from young shells, and afterwards finding the adult shell, which is very different, called it *Cerithium reticulatum.* It has for many years been called *Cerythium Sayi*, but a late author has again credited it to him, under the name of *Brittium nigrum.*

A species of *Succinea* (*S. Totteniana*) was dedicated to General Totten by Mr. Isaac Lea, of Philadelphia.

Conchologists are also indebted to General Totten for the discovery of means for the preservation of the epidermis or periostraca of shells, which is in many species so liable to crack, and this recipe has been received with much approbation by many collectors who have found it to supply a want much felt. The valuable collection of rare shells which he made at this period of his life he presented to the Smithsonian Institution, without the usual condition that it should be preserved separately, but to be used most advantageously for the advancement of science to complete the general collection of the Museum, or for distribution as duplicates to other establishments.

In the "Annals of the Lyceum of Natural History of New York" for 1824 (vol. i. pp. 109–114) he published "Notes on some new Supports for Minerals, subjected to the Action of the Common Blowpipe." These researches on the use and power of the blowpipe appear to have been incited by an article of James Smithson, the subsequent founder of the Smithsonian Institution, and the memoir of Totten commences with a reference to and rehearsal of the experiments of that gentleman, as detailed in a letter to the editor of the Annals of Philosophy. Smithson, it was remarked, had communicated several ingenious modifications of Saussure's process with supports of splinters of sapphire, which process, he observes, "has been scarcely at all employed; owing partly to the excessive difficulty, in general, of making the particles adhere, and in consequence of the almost unpossessed degree of patience required and of the time consumed by nearly interminable failures." Detailing the processes of Mr. Smithson, three in number, and the success of that gentleman, he adopted a modification of Smithson's third process, having recourse, as a support, to a portion of the mineral itself, which he designed to expose to the action of the flame. "Instead, however, of taking upon the point of platinum wire a very minute portion of the paste made of the powdered mineral," according to Mr. Smithson's method, he "formed a paste by mixing the powder with very thick gum-water and rubbing a little of it under the finger, formed a very acute cone, sometimes nearly an inch in length, and generally about a twentieth of an inch in diameter at the base." To the apex of such cones, the most minute particles would adhere under the strongest blast of the blowpipe, and being insulated by the destruction of continuity of the particles of the cone, the flame could be directed upon it with undiminished fervor. Experiments were made on a number of minerals, confirming those of Mr. Smithson, and greatly extending the power of the blowpipe, and he was thus led to add to the three classes divided in relation to this instrument a fourth, namely, "such as are fusible, *per se*, in microscopical particles."

The attention of the inhabitants near the shores of the great lakes of the North had often been arrested by the sudden disappearance in the spring of the ice on the surface. The lakes would be covered with a continuous sheet of solid ice in the evening, and in the next morning all would have vanished. Wild speculations had been entertained as to the explanation of this phenomenon previous to the investigation of the subject by General Totten, who presented an article on the subject to the American Association for the Advancement of Science at the Springfield meeting in 1859.

From this it appears that his attention had been directed to ty years before at Plattsburg, N. Y. Ice is composed of a congeries of prismatic crystals, whose axes are at right angles to the surface of the mass. "Examinations then and afterwards made of floating fresh-water ice have shown that the natural effect of the advancing year is gradually to transform ice, solid and apparently homogeneous, into an aggregation of these irregular prismatic crystals, standing in vertical juxtaposition, having few surfaces of contact, but touching rather at points and on edges, and kept in place at last merely by want of room to fall asunder. Until this change has somewhat advanced, the cohesive strength of ice of considerable thickness is still adequate to sustain the weight and shock of the travel it had borne during the winter, but becoming less and less coherent by the growing isolation of the prisms, or more and more 'rotten' as the phrase is, though retaining all its thickness, the ice will at last scarcely support a small weight, though bearing upon a large surface; the foot of man easily breaking through, and very slight resistance being made to the point of a cone." The points of contact of the particles being destroyed, each will drop into the position in the water below required by the place of its own centre of gravity—that is to say, it will be upon its side, exposing large surfaces to the action of the warm water. With the ice in such condition, a heavy wind will cause the disruption of the particles and the speedy disappearance would be the consequence. This remark of General Totten as to the crystallization of ice has since been extended to nearly all substances, which in becoming solid assume the crystallized form. The axes of the crystals tend to assume a position at right angles to the surface of cooling.

As illustrative of the mind of General Totten, it may be stated, that he seldom failed to give valuable hints for the improvement of processes or inventions which were brought before him in the course of the discharge of his numerous official duties. Among these was an instrument for ascertaining the daily amount of evaporation from a given surface by means of the descent of water contained in an inverted graduated tube, the open end of which was immersed in the basin from which the evaporation took place. With a slight correction for variation in barometrical pressure, this instrument gives, with more precision than any other with which we are acquainted, the amount of evaporation.

I have, Gentlemen, thus faintly and inadequately sketched the life and services of our departed friend and associate; but, faint and inadequate as my sketch may be, I feel confident that every one will recognize in it the lineaments of a great and true man. Labors so protracted, results so important and varied, it is the destiny of but few to achieve, and for him who achieves them may justly be claimed a high niche in the temple of Fame, and the grateful homage of the patriot and of the seeker after Truth. One of the oldest of the corporators of this Academy, it was permitted him only to contribute his past labors and his shining example. But these are indeed a rich legacy. Proud, indeed, may this youthful institution be that it can enroll among its members the name of Joseph Gilbert Totten—proud too, may each one whom I now address—each one of its members—be, if he shall achieve but a far less claim to recognition among men of science. To the aged among us—to those who were young with him, and like him have crowned a life of toil by honorable achievements—I need not speak. *They* require no example, and they may feel in contemplating his history an additional assurance that their own works too "shall praise them." To the more youthful or to the middle aged, who have just commenced, or but partially accomplished, the steep ascent which leads to honorable fame, his life is precious in its teachings.

He was a patriot in the broadest and best sense of the term. To his country he had given himself, and every faculty of his being was devoted to her honor and welfare—realizing almost literally the thought of Rousseau, "the child on entering life ought to see his country, and to the hour of his death to see but her."

Like all who have left lasting results for the benefit of their country or of mankind, he was a hard worker. But ill-regulated labor, however arduous, could never have accomplished what he accomplished. Beyond all men I ever knew, he was *systematic;* and few indeed are the examples of a life, in *all* things, so perfectly regulated. The beautiful *order* which pervaded all that he did is scarcely less worthy of study and admiration than the achievements to which it so materially contributed.

He was no trifler with the realities of life, who dallied with them for his pleasure or who wielded them as instruments of ambition or self-interest. To him, as to all true men, the meaning of life was concentrated in one single word, DUTY. This "chief end of man," which is to glorify God by obedience to his laws in the use of the faculties he has bestowed, was his ruling principle—the celestial cynosure to which his eye was ever directed, and from which no allurement of lower motives could divert it. Nor was his sense of duty of that frigid, repulsive nature which reduces the conduct of life to a formula, and, substituting rules for emotions, seems but a refined selfishness. He was warm and sympathetic, finding his chief happiness in the pleasures of domestic and social intercourse, but singularly susceptible to everything that ministers to innocent enjoyment.

Perhaps no more striking illustration than his history affords could be found of the truth that the path of duty is the path of happiness. His life was eminently a happy one, and his, indeed, was that "peace of mind which passeth understanding." Though devoted from his youth to the military service of his country, and doomed to the vicissitudes of a soldier's lot, he was permitted to a greater degree than most men to enjoy the blessings of the domestic circle. There, indeed, he sat enthroned, the idol of a family of whose supreme affection and immeasurable devotion he was the object. Nor dare we call those blows by which a Heavenly Father reminds us that this world is not our "abiding place," and teaches us to look beyond to "an house not made with hands, eternal in the heavens," as sources of unhappiness to him who receives them as from the hand of One "who chasteneth whom he loveth." One by one he lived to see all his three sons, two of his four daughters, and finally the companion of the joys and sorrows of so many years, precede him to the grave.

Beautiful beyond all else that earth presents is that conjugal companionship, so touchingly depicted by Burns, which, beginning in youth, is permitted to continue unbroken till the Psalmist's period of life is overpassed. During the later years of their lives, Mrs. Totten, no longer bound to the domestic hearth by the cares of a growing family, became truly an inseparable companion. Never, when it was at all practicable to have her with him, did he ride or walk, or make a journey, or perform one of his periodical tours of inspection, without her companionship; nor could one see them together without feeling that they presented a model of whatever is amiable and lovely in the conjugal state. If he was to her the embodiment of all that is most worthy of respect and love in man, not less marked was his deference to her. In her own sphere—as woman, wife, mother—she was supreme, and her judgment his law. When, but two years before his own death, she was somewhat suddenly called away, it seemed as if he regarded it as a message from on high, "set thy house in order, for thou shalt die and not live." No murmur escaped his lips, and no long-continued sadness clouded his brow, but there was an unwonted gentleness and quietude in his demeanor—a softening as it were of his nature—which revealed how deeply "the iron had entered his soul." His health and bodily strength seemed to continue little impaired, and his devotion to the duties of his office undiminished. But once, during a life protracted beyond the usual span, had that powerful frame submitted to the sway of sickness, and he seemed to have unusual promise of a still further protracted life. But such promises proved deceitful. Early in March, 1864, he was attacked with pneumonia. His illness was not at first deemed alarming, and, indeed, at one time he was supposed to be convalescent, but a relapse ensued, and on the 22d of April he expired, having borne the sufferings of his sickness with cheerfulness and resignation, and retained to the last the perfect use of all his mental faculties. He had long been a member and communicant of the Episcopal Church, and died in the Christian's hope of a joyful resurrection.

Gentle, kind, and good; mild, modest, and tolerant; wise, sagacious, shrewd, and learned, yet simple and unpretending as a child—he died as he had lived, surrounded by hearts gushing with affection, and the object of the respect and love of all with whom he had ever been associated.

The greatest of sculptors, the greatest of painters, a man unsurpassed in boldness and originality of thought, and whose name is among those of the few whose genius overpasses the limits of country and claims homage from all mankind—Michael Angelo—in a work stamped with the maturity of his powers, carved a figure known to the world as "Il Pensiero," or *Thought.* There exists in art no other personification of meditation—no other type of self-collectedness and profound thought.

The sculptor arrayed it not as a philosopher, as a monk, as an artist, as a theologian, as a scholar, nor even as a pope. And yet these different types of thinkers were not wanting in the past or present of the age and country of a Raphael, of a Correggio, of a Leonardo da Vinci, of a Dante, of a Savonarola, of a Marco Polo, of a Columbus, of a Machiavelli, of a Galileo, of a St. Francis de Assis, of a St. Thomas Aquinas, of a Julius II., of a Leo X., and of a Clement VII.

How, then, has Michael Angelo arrayed his personified "Thought"? In the garb of a SOLDIER, upon the breast the cuirass, upon the brow, wrapt in meditation, the iron casque of the man of war. The great sculptor has divined the mysterious cause why, among all people, among all classes, and in all epochs, the soldier is honored. Instinct teaches the people, and genius taught Michael Angelo, that among so many glorious examples, among so many immortal victims, so many illustrious martyrs or devotees of thought, illustrating an age or a country, the soldier stands forth pre-eminently, in all ages and in all countries, the victim always ready, the defender always armed, the servant, the apostle, and the martyr.

It is the Christian version of the ancient allegory which made Minerva issue from the brain of Jupiter: Minerva, or *wisdom armed*, the helmet upon her brow, the sword in her hand.

Will the foregoing paragraphs, which I have translated somewhat freely from the "Soldat" of Joachim Ambert, a work devoted to the illustration of the Soldier's career, be deemed an immodest or extravagant glorification of the profession of arms? Far be it from me to exalt unduly that profession, but I would at least make a claim for it, the more necessary since popular apprehension tends to lose sight of the thinker in the man of force and of blood, that, more than any other, it embraces all sciences and all branches of human knowledge, and leads its followers into vast and diverse fields of thought. Let the illustrious dead be our witnesses; that idea which the genius of a Michael Angelo inspired and embodied in marble, that idea which the lives of a Cæsar, a Frederic, a Washington, a Napoleon, and a Wellington have justified; the union of FORCE and THOUGHT finds yet another and a varied illustration in the accomplished soldier and profound thinker whose life and works we now commemorate.

APPENDIX.

RESOLUTIONS OF THE LIGHTHOUSE BOARD.

Resolved, That the members of the Lighthouse Board feel most deeply the loss sustained by the branch of the public service under their charge in the death of Brevet Major-General Joseph Gilbert Totten, who has been one of the most useful and active members of the Board from its first appointment in pursuance of law in 1851, under the Secretary of the Treasury, as a temporary Board of Inquiry into the Lighthouse Establishment of the United States, through all the years of organization of the establishment and of its executive duties.

Resolved, That the high scientific attainments, the admirable administrative qualities, the perfect knowledge of general principles, and attention to every minute detail of the system, impressed the mental and moral qualities of General Totten upon his associates in a way to make his mind eminently a leading one of the Board, while his suavity, patience, perfect amiability, and retiring modesty rendered him one of the most charming of associates in executing work to which he was so much more than sufficient.

Resolved, That in the discharge of the duties of inquiry of the first Board, the resulting organization, the adoption of the present system of lighting by lenses, the subject of construction, theoretical and practical, and the use of materials, the experience and experimental knowledge of General Totten were of the highest value to the Board, and his careful application of the sciences was of the greatest importance to the Lighthouse System; and that in the large qualities of common sense in all the transactions of the Board, general as well as technical, and in his high sense of justice directing great mental power, the Board constantly felt the support of General Totten as one to be relied upon for guidance in all difficult questions of administration.

Resolved, That the affectionate qualities of General Totten's heart so endeared him to his colleagues, that in now expressing themselves in regard to his death, they are fully prepared to share to the utmost the deep grief of his family, to whom they offer their sincere condolence for the loss of one not to be replaced, but to be ever mourned as the true, devoted, and sincere friend.

Resolved, That a copy of these resolutions be transmitted to the family of General Totten, and to the Honorable Secretary of War, and to the Honorable Secretary of the Treasury.

Resolved, That these proceedings be published in the Washington newspapers.

MEMOIR

OF

BENJAMIN SILLIMAN, SR.

1779-1864.

BY

ALEXIS CASWELL.

READ BEFORE THE NATIONAL ACADEMY, JAN. 25, 1866.

BIOGRAPHICAL MEMOIR OF BENJAMIN SILLIMAN.

MR. PRESIDENT AND GENTLEMEN:—

IN performing the duty assigned me by the Academy—that of preparing a memoir of a venerable and lamented associate, Professor Silliman—I have found myself embarrassed on two accounts: First, for the want of that personal acquaintance without which it is difficult to apprehend correctly those habits of thought and traits of character which it is my purpose to develop; and secondly, from being called upon to appreciate scientific labors out of my own field of study, and where I am little familiar with the details of scientific progress, and therefore specially liable to err. I am quite aware how inadequate any sketch of his character from me must seem to those who knew him well. Under these circumstances the rectitude of my intention will perhaps shield me from the severity of criticism.

The facts and dates which I shall have occasion to use have been derived to a considerable extent from an article under the word "Silliman," in the "New American Cyclopædia," understood to be sanctioned by the intimate friends of our deceased associate, and from a commemorative discourse of President Woolsey, delivered in the Central Church in New Haven, November 28, 1864.

Benjamin Silliman was born on the 8th of August, 1779, in the town of Stratford (now Trumbull), in the State of Connecticut. He was the son of General Gold Selleck Silliman. The Silliman family is supposed to be of Swiss origin. From the early settlement of the country they had been residents of the neighboring town of Fairfield. In July, 1779, the British forces, under Governor Tryon, invaded the maritime towns in the vicinity, carrying consternation to the inhabitants, and conflagration and pillage to several of the towns and villages. The family of General Silliman sought refuge in the town of Stratford, somewhat removed from the coast. And it was there, as before stated, that the subject of this memoir was born. It may be proper to add, that General Silliman graduated at Yale College in 1752, was a lawyer by profession, and an ardent patriot. During the Revolutionary struggle he rendered honorable service to his country, and evinced a devotion to the principles of liberty that might well become a descendant of the heroic and liberty-loving Swiss.

We have not at hand the means of tracing the childhood and early youth of young Silliman. At the age of eleven years he was bereft of his father, and was left to the fostering care and guidance of his mother. It is a sufficient indication of his diligence and aptitude in learning, that he was fitted to enter Yale College at the early age of thirteen years. His older and only brother, Gold Selleck Silliman, who still survives him, was a member of the same class. They both graduated in 1796.

We have now before us a young man of seventeen years of age, deeply imbued with religious sentiments, honorably distinguished as a student, and emulous of rivalling him who was foremost in the pursuit of good learning. To these advantages he united those of a fine physical constitution, and a kindly and pleasing address. With such "vantage-ground" to start from, we might confidently predict that, to whatever field of study he might turn his attention, his life would prove a success.

To talented and ambitious young men the profession of the law was then as now, and probably more then than now, the road to honor and fortune. Following in the footsteps of his father, young Silliman turned his attention to the study of the law. While prosecuting these studies, at an interval of three years from the time of his graduation, he received the appointment of Tutor in his Alma Mater. His last collegiate year was spent under the Presidency of Dr. Dwight, who no doubt saw in his youthful pupil those elements of character which fitted him for the duties of a college teacher. His name first appears on the catalogue as a tutor in 1799. He held the office for three years. In connection with his duties as tutor, he continued to prosecute the study of the law, and was admitted to the bar of New Haven in 1802. But another field of labor awaited him, for which no doubt the study of legal principles, and especially the law of evidence, had given him a most valuable preparation.

Chemistry and Natural History had begun to attract the attention of educators. They had heretofore been regarded more as an adjunct to the medical profession than as a branch of general education. The science of Chemistry was then in its infancy. Its foundations had been laid, and it was destined to a rapid growth. Priestley had shown the existence and properties of Oxygen. The important doctrines of latent and specific heat had been discovered by Black. Cavendish had shown the existence of Hydrogen as a distinct fluid, and had succeeded in the decomposition of water. Lavoisier had demonstrated the chemical changes involved in combustion and evaporation. Dalton had explained the properties of vapors and gases, and especially had discovered the law of combination in definite proportions, and of chemical equivalents. Cuvier in the meridian of his glory was building up the great science of Comparative Anatomy, and connecting the animal structure of long ages past with that of the living present. Davy and Berzelius and Gay Lussac were just entering on their several careers of discovery, which have rendered their names illustrious in the history of science. The science of Geology, as now understood, had then no existence.

With these facts before him, President Dwight saw the importance of making Chemistry and the natural sciences a part of general education. He discerned in his young friend those endowments and aptitudes of mind which promised success in these departments of science. He accordingly, in 1802, urged upon Mr. Silliman the expediency of abandoning the profession of the law, and of devoting himself to science. The suggestion was adopted, and the corporation of Yale College in that year elected "Benjamin Silliman, Esq., as the Professor of Chemistry and Natural History." It is our impression that there were at that time only two of our collegiate institutions where instruction was given in Chemistry—those of Harvard College and the University of Pennsylvania.

Professor Silliman did not immediately enter upon the duties of his new office. He took time for preparation. Portions of two winters were spent in Philadelphia, as a student of Dr. Woodhouse, prosecuting his professional studies under advantages which probably no other American city could then furnish. Dr. Hare had at that time just invented and brought into use the Oxyhydrogen or Compound Blowpipe, which generated an intensity of heat hitherto unknown to the Laboratory, and gave to science a new and efficient means of research. It was fortunate for both, perhaps, that Professor Silliman was engaged with him in many experiments with this instrument. His first course of lectures was given in the winter of 1804, and repeated in 1805. With a view more fully to prepare himself for the duties of his professorship, he determined to avail himself of the advantages of foreign schools of science, and accordingly sailed for Europe in the spring of 1805. He remained abroad somewhat more than a year, attending lectures in London and Edinburgh, and devoting a portion of his time to travelling. In 1810 he published an account of his travels, entitled "Journal of Travels in England, Holland, and Scotland in 1805–06," in 2 vols. 8vo., which, in a subsequent edition, was printed in 3 vols. 12mo. This work is replete with useful and interesting matter, reflecting in an easy, perspicuous style the impressions of a diligent observer of men and things. It was widely circulated, and gave to the author an agreeable introduction to the reading public.

During this residence abroad he had the opportunity of becoming acquainted with many of the foremost scientific men of that period. Among others he mentions Dugald Stewart, Professors Hope, Murray, Playfair, Jamieson, and Seymour. In the preface to his Treatise on Chemistry, he acknowledges special obligations to his former teachers, Professors Murray and Hope of Edinburgh. Nor did he fail—as who would?—to embrace the opportunity of listening, in the House of Commons, to the eloquence of Pitt and Fox, Sheridan and Windham.

On his return from Europe, in 1806, Professor Silliman resumed the duties of his professorship, embracing chemistry, pharmaceutics, mineralogy, and geology, which he continued to discharge with ability and rare popularity for a full half-century. He did not during this entire period have under his charge all these subjects, but it was only in 1855 that he relinquished his post as a college teacher. Very few men in any department can show a scientific career so laborious and so long continued.

Of the results of the instructions given to his college classes, I shall speak further on. But I may here say, that it was not the habit of his mind to confine himself to any single inquiry, or to any narrow routine of study. Whatever of scientific interest presented itself in any direction was sure to attract his attention. Though not to be placed in the list of great discoverers, he was among the earliest, in the progress of chemical science, to verify the discoveries of others, and so to illustrate and incorporate them in the body of science as to make them accessible to his pupil. The discovery of new truths is restricted to the fortunate few; the diffusion of them belongs to the practical, diligent many. A brilliant reputation crowns the former; comprehensive usefulness is the reward of the latter. Professor Silliman, pursuant to the practical bent of his mind, appears to have made the diffusion of knowledge his chosen field of labor. He never lost sight of the general interest and public utility of science, yet this characteristic of his mind did not prevent him from prosecuting at times laborious original researches. In 1811 he instituted an extended course of experiments with Hare's blowpipe, in which he succeeded, as he tells us, in melting lime, magnesia, rock-crystal, gun-flint, corundum gems, and a long list of the most refractory minerals, "the greater part of which," he adds, "had never been melted before."[1] A detailed account of these experiments was published in the Transactions of the Connecticut Academy of Arts and Sciences, in 1812.

On receiving intelligence of Sir Humphry Davy's discovery of the metallic bases of the alkalies, he immediately repeated his experiments, and "obtained, probably for the first time in the United States, the metals potassium and sodium."[2] While conducting some experiments with a powerful Hare's Galvanic Deflagrator, in 1811, he observed that the charcoal "point of the *positive pole*" instantly "shot out" towards the *negative pole.* And on further examination he found that there was a corresponding cavity on the point of the negative pole. He hence inferred that there was an *actual transfer* of the matter of the charcoal points from one to the other. He further found, on careful examination, that the charcoal *was fused.* An account of this interesting discovery is given in the fifth volume of the Journal of Science. It is claimed for Professor Silliman that

[1] Journal of Science, vol. i. p. 99. [2] Am. Cyc., § Silliman.

he was the first to establish *this transfer* of the *particles of carbon*, and the first also to *fuse carbon* in the voltaic arch.

Professor Silliman early felt the necessity of having some medium of communication between the cultivators of Physical Science and Natural History in different parts of the country. He saw how much science abroad was indebted to such journals as "Thompson's Annals of Philosophy" in England, and the "Annales de Chimie et de Physique" in France. He resolved on establishing a similar journal in this country, which should present to the public at brief intervals the results of scientific research, and by that means accomplish the two objects of diffusing information and stimulating inquiry. He accordingly, with pledges of assistance from a respectable corps of contributors, commenced the publication of the "American Journal of Science," more popularly known as "Silliman's Journal." The first number bears the date of 1819. For twenty years he was the sole editor, and the senior editor for eight years longer. He continued it under many embarrassments, and with far less patronage than its merits deserved. For a long time his own labors, which were never small, may almost be said to have been gratuitous; and not unfrequently the expense of bringing out the numbers became a charge upon his private funds, at least till generous friends came to his relief. Whatever this journal has done for American Science at home and abroad, and how much it has done every one knows, it was the creation of Professor Silliman. Under the management of a man of less energy, less confidence of hope, less devotion to the interests of science, less practical tact and administrative ability, the American Journal of Science would probably be remembered only as a premature and unsuccessful attempt to follow in the footsteps of older and more scientific nations.

Professor Silliman wielded a prolific pen. In 1820 he published, in a duodecimo volume, the incidents and observations of a journey from Hartford to Quebec. This journey was performed by slow and easy stages, and the volume abounds in pleasant descriptions of the different towns through which he travelled, with historical reminiscences and notices of geological formations.

In 1829 he edited an edition of Bakewell's Geology, and added, in an appendix, a copious compend of his own course of lectures to his college classes. In this compend the author presents a clear and simple statement of the facts and principles of the science as they were then understood, basing his arrangements, as he remarks, "upon the great outlines of the Wernerian plan." Without following any one as an authoritative guide, he evidently accords to Werner a degree of merit which later writers, as I apprehend, have not found reason to bestow. He says, in his preface, "It has become fashionable to decry Werner; but, without being his blind admirer, I may be permitted to ask, Who has done more for Geology, and who has done it better?"

In the controversy so long and so fiercely maintained respecting the Mosaic account of the Creation, he gave his decided support to the defenders of Scripture. He saw no necessary discrepancy on that subject between the teachings of science and the teachings of revelation. "The writer," he remarks in his preface, "after studying the subject for many years, has formed the opinion that the geological facts are not only not inconsistent with sacred history, but that their tendency is to illustrate and confirm it." With respect to the Mosaic account of the *Deluge*, he expresses himself even more strongly. "Geology," he says, "fully confirms the Scripture history of that event."

In 1830 he published an elaborate treatise on General Chemistry, in two volumes, octavo, entitled "Elements of Chemistry, in the order of the Lectures given in Yale College." It lays no claim to originality in the treatment of the subject. From the results of his own laboratory, and from his much reading, he gathered up all the known facts and laws of the science, and embodied them in a form which he deemed most convenient for instruction. His object, as expressed in his own language, was "to unite copiousness with condensation, perspicuity with brevity, and a lucid order and due connection of subordinate parts with a general unity of design." The work was, we believe, well received by the scientific public, and somewhat extensively used for the purpose of elementary instruction. In the judgment of a contemporary journal entitled to high consideration, "it was a work that was needed," and that was "eminently adapted to the objects for which it was prepared."

In 1851 Professor Silliman made a second visit to Europe. Forty-five years had wrought great changes in the scientific circles familiar to his first visit. Many whom he had once known were no more. He had the happiness, however, of personally meeting many others whom he had long known as scientific correspondents. The account of this visit was given to the public in three volumes, duodecimo, in 1853. It was a work well stored with careful observations and interesting narratives, thus recalling many agreeable reminiscences in the minds of those who have visited the same scenes, and communicating much useful information to those who have not. To show the public appreciation of this work, we may remark that, while new works of the same general description have been constantly teeming from the press, this has already passed through six editions.

I have thus briefly referred to the published works of Professor Silliman. But these do not, by any means, comprise the whole of his scientific labors. His special field was the diffusion of science; and his special gifts and acquirements made him one of the most popular scientific lecturers in the country. His commanding presence, his urbanity of address, his wealth of knowledge, his ready and graceful elocution, were all fitted to win the public favor, and secure for him a large and delighted audience wherever it was his pleasure to speak. Without being profound or original, he selected from the great storehouse of knowledge, all familiar to him, so judiciously, and threw such an enchantment around his theme, that all felt a kindling of enthusiasm as they listened. They drank in the doctrines of latent heat and chemical equivalents, saw through all the forms and laws of crystallization, and could plainly read in minerals, and fossils, and rocks of the fields, the geologic eras which stretch back into the immeasurable past, where no human eye ever saw. It was the power of personal inspiration that seemed to quicken their intellects.

Between the years 1834 and 1845, Professor Silliman delivered courses of scientific lectures in nearly all the large cities of the country, ranging from Boston to New Orleans. He gave four courses before the Lowell Institute in Boston, "Treated everywhere," says President Woolsey, in speaking of these lectures,—"treated everywhere with the highest consideration, welcomed by the numerous sons of Yale dispersed through this broad land, he had almost a triumphal progress, and widely diffused, it is believed, a taste for physical science."

Such is a brief summary of the scientific labors of our deceased associate. I can recall but few men who have labored so long, and done so much. But my task would be incomplete without some additional remarks illustrative of his character and services.

In the general retrospect of his life, one cannot but be struck with the amount of labor which he performed. The superintendence of his journal, preparing its articles, carrying on its large domestic and foreign correspondence, and looking after its insufficient finances, was itself no easy task. But to this he added almost daily lectures to his classes, often requiring much preparation, and yet found time to prepare books of instruction, and lectures for the public.

It seems to me that the *utility* of *science*, in its broadest sense, was always uppermost in his mind. He is always tracing abstract principles to their practical applications. In his several books and papers, he aims at the accomplishment of useful ends. His style of writing looks to this. It is direct, simple, perspicuous. Its only object seems to be to expound clearly the subject under consideration. It is business-like. It reads as if the author had too many important matters on his hands to occupy himself in the mere refinements of style.

We have already referred to the distinction between the discoverer of new truths and him who diffuses them abroad and gives to them their practical applications. The former is testing the powers of nature by the crucible and the balance and all those reagents which bring into play the affinities of matter; the latter is acting upon the intellectual powers of the community, and putting in motion far and wide over the land those mental agencies which result in wider general knowledge, higher culture, sounder practical judgments, and more productive industry. It is sometimes difficult to say which of these two classes of laborers confers the largest benefits upon the world. Nor, indeed, need we attempt to decide upon their respective merits. It is sufficient that they are both necessary to the highest ends of science. It was the fortune of our friend to act, for the most part, as the diffuser of knowledge. And by what criterion shall we estimate the obligations which we owe to him in this respect?

It was said of Dr. Black, by a very competent judge[1] of his scientific merit, that "his influence on science was chiefly exerted through the medium of his pupils and of his intercourse with

[1] Prof. J. D. Forbes, Encyc. Brit., 6th Dissertation, p. 927.

general society." With equal truth may this be said of Professor Silliman, and especially when we consider the vast extent of his field of instruction. Among the pupils of half a century how many have caught the enthusiasm of the master and given their energies to science, and placed their names high on the list of its honored cultivators! How many hundreds and thousands of those who, in different cities, have listened to his eloquent lectures, have learned to appreciate science, and gather refined pleasure from its culture, and give to it their hearty patronage! How regularly and how widely has his Journal carried to the reading public intelligence of the latest discoveries, and the best practical applications of science!

Considering all this, who shall say that his efficient influence has not been felt in every institution of learning, in every profession, nay, in every workshop, and every cultivated field in this broad land of ours!

It is undoubtedly true, as has been stated by one of his accomplished colleagues, that "his mind was of the rhetorical, not of the analytical cast." He seldom expended his energies in attempting to unravel the dark and tangled web of science. Profound, original thought was not the productive element of his mind. He followed in the footsteps of the explorer, and quickly gathered up whatever was valuable in the way, and sent it forth on its mission of utility. In view, then, of what he has done for Chemistry, for Mineralogy, for Geology, and for the general diffusion of knowledge, we may well say that the name of Silliman will ever be an honored name in the annals of American Science.

Thus much we think may be justly and pertinently said of the scientific career of Professor Silliman. But he was more than a scientist: he was a *citizen*, a *patriot*, and a *Christian*.

As a *citizen* we believe he was universally honored and beloved. He was in every good work. His kindly interest in those about him, his uniform urbanity, his readiness to oblige, made friends of all who had the opportunity of knowing him. It will not be too much to say that his fellow-citizens by common consent regarded him as their first citizen. He was their representative man. His presence added dignity to every assembly. His counsels were listened to as words of patriarchal wisdom and authority.

As a *patriot* it is well known how ardent he was in the defence of the Constitution and the laws, when they were imperilled by the machinations of disloyal men. When the conflict arose between slavery and freedom in Kansas, he threw the whole weight of his influence into the scale of freedom. He saw clearly that the ambitious designs of the slave power must be strenuously opposed and defeated at that point. He was satisfied, as many others were, that lukewarmness or indifference then might be fatal to the interests of freedom throughout the republic for generations to come. That was one of the turning-points in our national destiny. A profound regard for justice and the rights of humanity and the honor of the nation urged him to do everything in his power to prevent the further extension of slavery in the Territories.

When the purposes of the slave power culminated in armed secession, there was but one course before him. It was to sustain the government and put down the rebellion by every means in the power of a great and free people. In the disruption of the government, and the establishment upon our borders of a political power based on human slavery as its "chief corner-stone," he saw nothing but national humiliation, disaster, and ruin. His country, entire and undivided, its Constitution and equal laws securing freedom and protection alike to all; these were the objects of his profound regard. And higher objects than these the loftiest patriotism has, perhaps, never achieved.

I have yet to speak of our associate as a *Christian*. Without this, all that I have said and all that could be said would leave his real character unfinished; nay, almost distorted and deformed. Early in life he became convinced of the truth of revealed religion and of his personal duty in response to its mandates. He made a public profession of his faith in Christ while a tutor in college, and became a member of the College Church. For more than threescore years, in all the relations of life, he exemplified the virtue of the Christian character. At the time of his death he was, with one exception, the oldest member of the College Church. If I may judge from the testimony of others, the lustre of his Christian character grew brighter and brighter as he drew towards the end of his pilgrimage. The contemplation of nature, no less than the sublime teachings of Scripture, inspired him with true devotion. His death was but the beautiful termination of a conscientious religious life. With physical powers far less impaired than is usual to his age, and with mental powers stil fresh and active, he died in the bosom of his family almost without warning, and without pain, on the morning of Thanksgiving day, November 24, 1864, in the eighty-sixth year of his age. He had just closed his accustomed service of prayer and praise, with a heart full of gratitude to God for the blessings bestowed upon him, he was uttering words of endearment and affection to members of his family when the summons came, and he was numbered with the dead. In contemplating a scene so touching, who can refrain from exclaiming, in the language of Scripture, "Let me die the death of the righteous, and let my last end be like his"?

Professor Silliman was twice married. He was most happy in his domestic life, and in the children and grandchildren who will delight to honor his memory, and bear onward the torch of science which he has laid down.

MEMOIR

OF

EDWARD HITCHCOCK.

1793–1864.

BY

J. P. LESLEY.

READ BEFORE THE NATIONAL ACADEMY, AUG. 9, 1866.

BIOGRAPHICAL MEMOIR OF EDWARD HITCHCOCK.

WE cherish the memory of the good and wise, not because they are rare, for the world is full of them; they exist in every society and grade of society, in every business and profession, even in the limited circle of acquaintanceship of every respectable person. But we cherish the memory of the wise and good, because it is dear to us, because we have been taught, encouraged, aided, cheered, blessed, and ennobled by them; and their memory is a continuation of their living words and deeds, and we can make it an heirloom for our children. A man to be remembered is a man to be spoken of. Even in the most barbarous aboriginal stages of the history of mankind, men here and there appeared, whose biographies, could they be written, the world could make good use of. In our own days of high civilization, almost every active life deserves a record. But the law of natural selection rules in literature also, and the struggle for posthumous fame, like the struggle for animal life, is crowned only in the persons of the best competitors. One of these favored few we celebrate this evening.

A man of religion, a man of science; in both, a docile student and an expert teacher; in both, enthusiastic and self-sacrificing; in both, gentle, persuasive, affectionate, sympathetic; in both, shackled by traditions which he both feared and hated to break, yet vigorously holding up his shackles and keeping abreast and in some respects ahead of the advancing age.

Such was Edward Hitchcock, one of the fathers of American Geology, and one who continued to the close of a long life to be an original investigator. A man of ardent fancy, impulsive, curious, and credulous; docile and teachable beyond any adult man of science I ever knew; modest to a marvel; yet, with all this, a man of sufficient self-reliance and determination for the most important practices of life, patient of difficulties, persevering and industrious for final success in any undertaking, sound in judgment, and disciplined in temper, a friend to all, and the friend of all, his whole career laid claims to eminence, which would have been pre-eminence in American Theology, had it not been for the interference of his science, or in American Science, had it not been for his devotion to the ecclesiastical and financial interests of the College, which he saved from premature decay, and refounded upon the deliberate sacrifice of his own ambition.

Edward Hitchcock was born in 1793. His father was a small farmer who had learned the trade of a hatter, had fought in the Revolutionary War, and was a deacon in a Congregational Church, a man of strong mind and steadfast piety, a genuine New England Puritan.

His mother was a high-bred New England woman, one of those perfect creations of divine skill by which the development of our race is guaranteed; a woman of quick intelligence, pure heart, and exquisite sensibility. The son was therefore born both to religion and to science. The keys of the spiritual and of the physical worlds were hid beneath his pillow. He heard told every morning the tremendous dreams of the Church, and became a poet. The Unitarian controversy made him a thinker. The Comet of 1811 made him an observer. Step by step his imagination and his understanding were unfolded, alternately and together; and neither at the expense of the other. The times were propitious. The nineteenth century opened when he was but eight years old, the age when the brain is fully formed and fit to begin its work. The harvests of New England are neither corn nor wine nor oil, but self-reliance and independence, economy and energy, intelligence, high aspirations, the power to learn and the right to teach, insight into the worth of ideas, and a scorn of facts which do not submit to universal laws, a curiosity bounded only by the limits of the possible, and a veneration for man as man; the master, not the slave, of circumstance. These were the influential forces which worked around our young philosopher and poet, educating him to become the intellectual teacher of his village (Deerfield) at the age of twenty-two, the religious teacher of the church at Conway at the age of twenty-seven, Professor of Chemistry and Natural History at Amherst at the age of thirty-two, chief of the Geological Survey of Massachusetts at the age of thirty-seven, Doctor of Laws from Harvard, and representative of American Science as first President of the American Association for the Advancement of Science at the age of forty-seven. At fifty-one he represented both science and religion as President of Amherst College, and continued to be thus one of the foremost men of his age for twenty years longer, until his death in 1864. A venerable life!

There is something not a little awful in exploring the domains of a life that is not ours. It is a labyrinth illuminated with the faintest twilight; a group of caverns to be surveyed with ropes and torches, haunted by romance, and stocked with images to which the excited imagination of each spectator gives some different shape. The principles, the motives, of another man's soul are to me underground rivers, flowing in undiscernible abysses; and his thoughts flash before my eyes like Protei in the waters of the cavern at Adelsberg. What can I know of their birth, or of their true shapes and natures? I can see that many of them are blind; but I must argue that they are all well fitted for their native home. The good and the bad, the wise and the foolish, all add alike to the beauty of the entire universe. The biographical critic therefore runs a thousand risks, either of impertinently maligning the creature, or of presumptuously arraigning the Creator. Neither is all gold that glitters; and the biographer must not expect to be believed when he returns to the daylight of crowded life and describes his Wier's Cave as filled with exquisite carved statues of Washington, or the glittering crystals in the roof of his Mammoth Cave as equalling, in their brilliancy, number, and effect upon the senses, the stars in a tropical sky. Too much sensational biography has been allowed. Individual souls are worth no more to the race than individual soldiers to an army. Even in camp the waste is ten per cent. But the moment the army moves, the waste becomes thirty per cent. and forty per cent. Such is the waste of souls in time of spiritual excitement, in revivals of literature or religion, and in the periodical advancements of national politics towards a perfect socialism. Yet the histories of nations lost, and the biographies of souls wasted, deserve better to be written, because fuller of adventure, and therefore of instruction, than those of Rome and Cæsar. But the muse of history can only write in presence of its monuments. What botanist could succeed, were he to study only the fallen trunks and macerated leaves of the forest? The monuments of a life are its only guaranty of immortality; dim, mystical, and fragmentary though the hieroglyphics be from which they that come after are to make out the complexity and grandeur of the character of him who has gone before.

The man whose eulogy we read to-night has left us monuments enough. They stand in long lines above his resting-place, like the Menhirs of Carnac, vistas of monoliths. Some men are satisfied if they erect but one, like that which now lies broken into four fragments at Loc-Maria-Ker in Brittany, along the ground. The intellectual energy of other men survives in some Druid circle sacred to a single deity. But Edward Hitchcock lived a various life, and wrote of all that touched the deepest consciousness of his age. His monuments stand in parallel ranges. In Religion he wrote five volumes and thirty-seven essays, pamphlets, and tracts. In Science he published fourteen volumes, five pamphlets, and seventy scientific papers, on Botanical, Mineralogical, and Geological and Physical subjects, in journals and reviews. His works on Temperance are in three volumes and three smaller tracts. In early life he wrote a tragedy, the year the great Napoleon fell. And there are twenty-six titles given us of various other productions of his pen, which went to swell the current published literature of the times in which he lived. Other men write as much, and publish nothing. But who counts the half-cut stone still lying in the quarry as among the obelisks of Egypt? This man lived for his times, not for himself. He was no *dilettante*. The perfume of the flowering of his soul was not wasted on the desert air. He was no anchorite, but a true missionary both in religion and in science. He was not fond of that *dolce far niente* which confined the delights of the Decameron to a select circle of ladies, while the surrounding world was wretchedly perishing with the plague. He did not sympathize with the proud reticence of men of science who claim that the doctrine is esoteric; that to popularize science, degrades it. What he learned, he communicated, like an apostle. And if, like an apostle, his zeal led him to act or teach an error, he was ready afterwards, like an honest man, to make his recantation, and advance the general intelligence in that way also. But he was saved from making great or many errors by the patience and precision with which he worked.

The best illustration of his precision is afforded by the history of his controversy with Mr. Blunt, the republisher of the Nautical Almanac in New York. In 1811 young Hitchcock had used the telescope of Deerfield Academy for observing the comet. "The subsequent winter," he says, "was in good measure devoted to a reduction of his observations, and, as he had access to few books, he was obliged to calculate by spherical trigonometry many elements which, at this day, are found in the tables of practical astronomy. The mere effort to form an accurate idea of the numerous spherical triangles he had to construct was an admirable discipline, and their accurate solution not less so." In making these calculations he was obliged to use Blunt's Almanac, on the opening monthly page of which this challenge was ostentatiously printed: "Ten dollars will be paid on the discovery of an error in the figures." The young astronomer amused himself by collecting such errors, and mailed his collection to New York. In spite of the placard their value was unrecognized. He then published the list in the American Monthly Magazine. Blunt's ire was roused; he hastened to explain that, although "one Edward Hitchcock had made the discovery of some few errors in the astronomical portions of his Almanac, the portion devoted to the practical use of sailors would be found to be perfectly reliable, and was a thousand times more important." The young astronomer was soon ready with another list, taken this time from the tables of lunar distances, practical enough on shipboard. The publication of these twenty errors, and of thirty-five more six months later, were his only reply to the scurrilous attack of Mr. Blunt. True science received its proper reward. The boastful and stupid editor of the Almanac was compelled by public opinion to employ a competent person to recalculate the Almanac for 1819, and advertised the enlargement of his own ideas by prefacing in the new edition these more modest words: "It will afford much satisfaction and promote commercial advantages, if, on discovery of an error in any nautical work, publicity should immediately be given." No allusion, however, to "one Edward Hitchcock"—merely a presentation copy, in which thirty-five new errors were immediately discovered, announced, and acknowledged humbly by the editor. There is no estimating the value of such a bit of scientific history. When the young mountain poet of Israel encountered the giant Goliath of Gath, a slip of that young foot upon the rock, a quiver of the eyelid, would have changed the stream of history through all ages, and postponed the coming of Christ to save the world. But to the young poet himself, the prosperous issue of the adventure was more than the salvation of a world; for it made him the right arm of Israel, and the tongue of Christendom. The same law of the mutual intersubordination of the whole to the part, and of the part to the whole, however denied by the school of Buckle, holds good under all the disguises of modern socialisms. The young Hitchcock, in a moment of idle fancy, with the daring of a fresh observer who had never yet been punished for making a mistake, attacked one of the established institutions of the world, and, by his courage, clear sight, patience, and good nature, introduced a practical reform which was felt on every ocean round the world, and, at the same time, lifted himself to the platform occupied by recognized and experienced men of science, where he continued to observe with the same patient precision, and publish with the same courage all he knew.

He says in his autobiography, reviewing the list of his publications, that it seemed as if he had written and published too much—that, had he spent more time in preparing his productions, their literary execution would have been more creditable, and the thoughts more mature and effective; but the peculiar circumstances of his early life compelled him to a course which, probably, he adds, "were I to live my life over again, I should pursue essentially the same" But the subjects on which he wrote were novel, requiring original research, and the descriptions of them scientific accuracy rather than literary elegance. This is his self-excuse, gratuitous and unnecessary; for the style, especially of his later works, is sufficiently scholarly, and the order, as well as the expression, of his thoughts, lucid and complete.

This, however, is no place for the reading of a critical review of his geological or of his religious works. I can only group them in such a way before your imagination as to paint the foreground, the background, and the middle distance of his soul's life. In the foreground, the terraces of the Connecticut and Deerfield valleys, the fossil footprints on the quarries of Hadley, and the flattened pebbles of the gneiss; the middle distance full of the local geology of Massachusetts and Vermont, Martha's Vineyard, Portland and its vicinity, Texas, Western Asia, and the world at large, with a thousand physical and social subjects, all interesting to his active, serious, and affectionate mind; and in the background, Alps on Alps of sacred dogma and religious aspiration, with glaciers interspersed of cosmic speculations, and deeper vales of self-consecration, self-sacrifice, and beneficence, bearing their harvests of good fruit.

In the foreground of every life, distinguished from the common life of the crowd, lies some object characteristic and nominative, the seal and signature of that man's dæmon, by which he shall be recognized and spoken of forever. The print of a bird's foot on a slab of red sandstone is the *totem* of Edward Hitchcock. He was not the first to see these wonderful remains, nor even the first to see them with an eye of trained judicial and executive science. But though others built and owned the city, he carried off its gates upon his shoulders. His patience in examining these remains; his economical skill in collecting them; the taste and largeness of mind which he displayed in their arrangement, and the energy with which he pursued this new branch of Palæontology, until the world recognized its claims and learned its merits, entitle him to rank, at least, as the coequal of its true discoverer. Dr. Dean early convinced himself, and Dr. Hitchcock afterwards, that the vestiges were those of living creatures, birds wading on the estuary flats; and both together convinced the world of it. But, besides this, there was much more to do. Specific differences were to be determined. He, Hitchcock, determined one hundred and twenty species. Comparison with foreign specimens was indispensable. He made the finest cabinet in the world, and placed it at the disposal of students. He published plates and descriptions of its contents, so that geologists in other countries might discuss opinions. He exerted such an influence over the public mind that the State of Massachusetts became the publisher of the new department. No controversies will ever avail to divorce the name of Edward Hitchcock from that of Ornithichnology. His name has become itself an imprint —not a bird-track, but a bard-track—upon the rock. Sedgwick and the Cambrians, Murchison and the Silurians, Hugh Miller and the Devonians, Rogers and the Appalachians, Lyell and the Tertiaries, are not more household terms in the history of our science, than is "Hitchcock and the New Red Sandstone" of the Connecticut River Valley, with its beautiful trap ranges, Mount

Tom, Mount Holyoke, and the rest of them; and its Robinson Crusoe footsteps in the sand of an age so ancient that the silence of the dawn of an eternity seems brooding in it; broken only by the weird cries of these birds, or the horrid croaking of batrachians huge as our pachyderms, among whom they fed. This ancient mystery reminds one of the horrid stories of the haunted house of Pottsville, where the inmates would be sitting at their work, the doors would fly open, sighings would pass along the air, footsteps would be seen pressed into the soft plush of the carpet, but not a form possessing the solidity and heaviness of life could be once observed. Although the majority of these vestiges seem to have belonged to quadrupeds, yet a few of them were probably the tracks of bipeds; and even if these bipeds shall turn out to be reptilian in their principal features, and to belong to some synthetic type, like that expressed by the Solenhofen archæopteryx, the term "bird-track" will continue to be used for all of a trifid form, and Hitchcock will remain the great expounder of the difference.

His first account of them dates back thirty years. In 1836 he published his first description of the Footmarks of Birds (Ornithichnites) on the New Red Sandstone of Massachusetts, in the twenty-ninth volume of Silliman's Journal. He followed it up with a description of those found in Connecticut in the thirty-first volume; a general table of fossil footsteps in sandstone and graywacke in the thirty-second volume; five new species in the first volume of the Transactions of the American Association; still new species, with descriptions of coprolites, in the forty-seventh volume of the Journal; and an analysis of the coprolites in the forty-eighth volume. He described two more species in the fourth volume of the new series of the Journal, still more in the twenty-first volume. His first quarto volume on the Fossil Footmarks of the United States, from the Transactions of the American Academy, appeared in 1848, and additional facts respecting the Otozoum Moodii in the Proceedings of the Association for 1855. His quarto report on the Ichnology of New England appeared in 1858, with further remarks, in the Proceedings of the Association for 1860, and new facts and conclusions in the Journal for 1863. These are his monuments. Most men would consider them sufficient for one life. In his they merely mark an episode; but there were others: an episode only of his scientific life. I leave the notice of it here, with the remark that he worked in it almost alone, and that he has left it standing unaltered by the labors of others. His publications on this theme are not only classical, but standard. His determinations are of accepted authority, which no controversial doubts as yet obscure. I pass now to others of which this cannot be said—in which he has been a disciple rather than a master—and which are rather characteristic of the genius of the geologist, than influential in the progress of geology.

I refer first to the study of the Drift. In Structural Geology this is the great question of the day. The subject has extraordinary difficulties. Could we determine the cause of the drift deposits, it would explain much that is puzzling in all the formations, down to the very base of the Laurentian. The wildest speculations meet at this point of Geology. It is the horse-latitudes of the voyage. Forty years ago the Swiss geologists shocked the world with the announcement that all the giant blocks of primary rock which travellers see lying stranded half-way up the Jura had been carried thither by a forward expansion of the glaciers of the Alps, invading, oversliding, and deeply burying the entire plains of Switzerland. Twenty years ago Mr. Agassiz, having previously shown the Scotch and Welsh geologists the traces of a similar universal glacier, which once descended from their highlands and covered all Great Britain, appeared upon this side of the Atlantic to establish among us the grand mythology of universal ice. From Halifax to the Fond-du-lac, and from the Ottawa to the Ohio, he found its vestiges. And now he covers with it the entire water-plains of the Amazons, the Orinoco, and the La Plata, from the shores of the Andes to the sea, six millions of square miles of the earth's surface, a part of it directly under the equator and close upon the level of the sea.

But we are concerned, not with the truth of these ideas, but only with their introduction into America, and their partial adoption by Edward Hitchcock, towards the close of his life. I say their *partial* adoption, for in the discussions which ensued he exhibited his usual mixture of conservatism and love of new ideas. He was, as a man, both timid and adventurous. Adventurous and progressive where he thought he could see his way; hesitating and submissive to authority when himself in the dark.

And this composition of adverse habits, held in balance by circumstances, not by will nor by genius, made him a representative man—a geologist in whose writings one can read the halting progress of American Geology—its ignorance of its own past history, its premature intuitions, its ill-bred waywardness and levity, its abortive investigations, its double-minded instability, its feeble conservatism, its energetic radicalism, the fertility of its fancy, and the haziness of its judgment, its patience to wait, and its power to work, for what it is as ready to abandon in a moment for something new.

The subject of Surface Geology, involving, of course, the question of the Drift, early claimed his attention, for his Geology of the Connecticut was published in 1823, after it had appeared as an article in the very first volume of Silliman's Journal, one year previous to Eaton's first report on the Geology of the Erie Canal, and Olmsted's first report of the Geological State Survey of North Carolina. At that time the only recognized agency to which the drift phenomena could be ascribed, was that of moving waters. Deltas, terraces, drift boulders, and polished rock-surfaces were all explained in a vague and poetical way by diluvial floods. The grandeur of the phenomena was not appreciated, but their nature was. When, ten years afterwards, the brothers Rogers got the first true glimpse of Appalachian erosion in its immensity of breadth and height, the aqueous theory swelled to commensurate proportions, just as the ice theory has grown to suit the geographical development of the drift appearances.

Had Dr. Hitchcock been more of a poet, and less of a Yankee, he would have adopted an hypothesis similar to that of the Rogerses, and been hampered by it all his life. But he soon detected traces of another agency, and although the absence of Alpine summits from New England, and the distance at which the northern icebergs melted from its coasts, deprived him of opportunities for coming to a lively consciousness of his suspicions, they prepared him to accept the first instructions on the subject which were sent to him from abroad. He always maintained that he got his first clear views of the joint action of ice and water from the researches of Sir James Hall, although Murchison, in his anniversary address before the London Geological Society in 1842, accords the honor of inventing the glacio-aqueous theory, as Hitchcock named it, to Peter Dobson, of Vernon, in

Connecticut, whose first public communication on the subject appeared in the tenth volume of Silliman's Journal, in 1826, and whose letter to Dr. Hitchcock, in 1837, the latter never answered, but kept for six years among his papers, and only sent it for publication in the Journal in 1843, the year following that of Murchison's public indorsement of Mr. Dobson's views, as "a short, clear, and modest statement of the best glacial theory—the essence of the modified glacial theory at which geologists (says Murchison) have arrived after so much debate." Mr. Dobson described certain red sandstone boulders, too angular to have been rolled by floods, and scratched upon their inner sides, "as having been dragged over rocks and gravelly earth in one steady position;" adding, "I think we cannot account for these appearances unless we call in the aid of ice as well as water, supposing that they have been worn by being suspended, and carried in ice over rocks and earth under water."

These views of Mr. Dobson had been twenty years on record, but neglected, when they were thus quoted and complimented by the highest authority in Great Britain. It was at one of those epochs of excitement which occur periodically in the history of every science. Agassiz had appeared at Edinburgh; and for him to come was to see and conquer. Neither Murchison nor Lyell at that time accepted his glacial hypothesis in its broad applications to the circumpolar earth and the entire drift. But from that day onward the younger geologists, with Ramsay at their head, worked at it *con amore*, and strengthened its claims to acceptation by annual fresh discoveries; but they have finished by assigning to it such incredible omnipotence, and claiming for it such impossible activity, as its great master has never authorized. So that its reputation has been seriously compromised, and, as was inevitable, a reaction has set in. Our business hereafter will rather be to shield the glacial theory from undue disparagement than to complain of its extravagancies.

Dr. Hitchcock, with the enthusiasm of his nature, had at first expressed himself too favorably of this hypothesis. He retracted his expressions when called to account for them by Murchison. In an article which he sent to Silliman's Journal, July 5th, 1842, he insists that Murchison, in his Annual Address, ought not to have charged him with being an advocate of Agassiz's ideas in an unmodified form; for, "although the *Études sur les Glaciers* had, indeed, thrown a flood of light unexpectedly into his path, yet he had always thought, and still thought, that the moraines of America were produced by icebergs, and not by glaciers." "Whatever impression," he writes, "my language has conveyed, I now declare that I have never supposed it possible to apply the glacial theory of Agassiz to this country without modification. I stated [before the Association of Geologists at Boston, in April] my conviction that glacio-aqueous action has been the controlling power in producing the phenomena of drift, by which I mean the joint action of ice and water, without deciding which has exerted the greater influence."

These words give us a clear knowledge of the attitude of his mind in the presence of a discussion which filled the geological world with clamor at that time as it does to-day, and obliged every geologist to define his position. His slow and cautious disposition, disciplined by field work on the one hand, and by college lecturing on the other, restrained his imagination from adopting any large hypothesis, but confined him to a few familiar statements of mere fact. All he knew, or cared to know, or believed that any one would ever know, was, that a sheet of loose sand, gravel, and boulder rocks, bearing certain marks of moving force upon them, covered certain portions of the surface of the earth, and that this sheet had been spread out not wholly through the agency of water. "Whether the vast currents of water which must have been concerned were the result of the sudden melting of the thick belts of ice around the poles, as Agassiz supposes, or of the elevation of the regions around the poles, whereby an ocean was thrown over the land, agreeably to the views of De la Beche, or by the elevation of different parts of the continents from the ocean, while the greater part of those continents was beneath the waters, according to Lyell and Murchison, I do not feel competent to decide. I rest at present in the position that ice and water were both concerned, and am in doubt whether geologists will ever be able to go much further and remain upon the *terra firma* of logical induction. But to have reached this principle, in which I fancy nearly all geologists now agree, seems to me an immense advance on this subject, and for this progress in my own mind I feel greatly indebted to Agassiz." In another sentence he adds: "It will be seen that my mind was entirely unsettled as to the origin of the ice and water which have produced the drift, and that I was quite as favorably inclined towards the peculiar views of Mr. Murchison as of any other geologist."

These views, if they can be called so, were repeated by Dr. Hitchcock at the Albany meeting, in 1843, during a lively discussion on the Drift which was introduced by Dr. C. T. Jackson, with these words: "Many eminent men incautiously embraced the new theory, which, within two or three years from its promulgation, has been found utterly inadequate, and is now abandoned by many of its former supporters"—a rash statement, as we all now see clearly enough. Dr. Hitchcock saw its rashness then.

At the Washington meeting in 1844 he read a paper on the Berkshire trains, discovered by Dr. Reid. All that he knew of the Drift he had published the year before in his annual State Geological Report. This was a special and remarkable case. It has never been elucidated. Dr. Hitchcock describes the phenomenon, but leaves it unexplained. His conclusions are all merely negative, and exhibit, in a striking manner, the cautiousness and fidelity of his scientific methods. 1st. The blocks of the trains must have been scattered during the latter part of the drift period, and by the drift agent, whatever that was. 2d. It is impossible to explain the case by any merely aqueous theory of drift. 3d. It is equally impossible to explain it by icebergs; or, 4th, by river pack ice; or, 5th, by the medial moraine of a glacier; or, 6th, by reference to the unexplained patches of angular fragments on the Falkland Islands, described by Darwin. "In short," he concludes, "I find so many difficulties on any supposition which I can make, that I prefer to leave the case unexplained until more analogous facts have been observed."

At the meeting of the British Association at Edinburgh, in 1850, he read a paper upon his favorite subject, the terraces of the drift period, after he had made a visit to Wales, where he at once recognized the marks of the former existence of glaciers up to a certain height, above which he recognized the marks of mere drift agency, and to Switzerland, where he confirmed his faith in the views which Agassiz had taught respecting the former extent of the grand glaciers of the Alps. But his Massachusetts experiences had so prepossessed him with notions of *modified drift*, that he thought he could see how the moraine matter of the plain of Switzerland had been subsequently thrown into terraces. He was therefore prepared, on his return to England, to accept Ramsay's conjecture that there were two glacial epochs—one before, and the other after the drift.

The following year, 1851, he visited the White Mountains, and studied the effect of one of those tremendous stone-slides which have played so important a part in the reduction to its present level of the central *massiff* of New Hampshire, upon the face of the rock *in situ* over which it passed. Seeing no glacial markings whatever, he concluded that any aqueous theory of diluvial scratches must be insufficient. He had evidently come to feel the difference between the weight of a stone-slide, whether in or out of water, and the weight of a glacier or iceberg.

Finally, in 1857, appeared his contribution to the quarto publications of the Smithsonian Institution, called Illustrations of Surface Geology, in which he sums up his knowledge of the Drift. In the first part he compares the terraces of the Connecticut Valley with those of other regions. In the second part he discusses the modes and consequences of river erosion; and in the third part he gives the results of his previous five years' field work, devoted to the study of glacial striæ and moraines in the valleys of Massachusetts and Vermont. These moraines, he says, seem to him, like the Swiss moraines, to have been modified and obscured subsequent to their creation by another agency, which he does not distinctly call that of the Drift, but, as he expresses it, "by the long-continued presence and the action of water, as the surface emerged from the deep." Even at this late date, he had no distinct hypothesis to offer. He declared that he agreed more nearly with Mr. Redfield's views than any others. He thought "that the phenomena of boulders and drift should be attributed to mixed causes, and that the theories which refer these phenomena to the several agencies of glaciers, icebergs, and packed ice, are, in truth, more nearly coincident than is commonly imagined"! He found it (as Desor expressed it) "difficult to conceive how glaciers could exist and move in a wide and level country like the north part of the United States." And he winds up with these fine words, worthy of the man and of pure science, unsatisfactory enough to the theorist, but full of instruction for the neophyte: "I am aware that I am in conflict with the views of eminent geologists on several points; as I am, indeed, with my own opinions as held several years ago. And yet, for a long time, I have stood chiefly aloof from the various hypotheses that have been broached respecting Surface Geology. But I could not refuse to follow where facts seemed to lead the way. It becomes me, however, to be very modest in urging my conclusions upon others. If they cannot adopt my explications, I hope they will, at least, find my facts to be of some little service in reaching better conclusions."

I must now say a few words about a third subject of investigation which may possibly in future time conduce more to his reputation as an original observer and bold thinker in geology than any other: I refer of course to his extraordinary statements respecting the distortion of quartz pebbles in conglomerate rocks. It is possible that I may be giving to the father credit for what is due to the son. But the two worthy geologists of Amherst represent to the world as yet but one Hitchcock, so amicably have they married their hammers and clinometers together.

It was at the last meeting held by the American Association for the Advancement of Science before the breaking out of the accursed rebellion in the States of this Union devoted to slavery—the meeting of the summer of 1860, at Newport—that a paper was read upon the conglomerate pebbles of the cliffs upon the southern shore of Rhode Island; attempting to show that they had been pressed out of their original globoid shape, flattened, elongated, curved into sickle-blades, and otherwise distorted, like fossil shells in semi-metamorphic rocks.

The opinion was expressed that this process might be found to have been carried on in all rocks, to an extent only limited by their degree of metamorphism. Of course the few geologists present at the meeting were not prepared to recognize the fact of such distortion in the evidently water-worn slaty pebbles laid before them as specimens. Nor will any geologist, I believe, who may have had a large experience solely among the conglomerate outcrops of No. IV., No. X., and No. XII. of the Palæozoic system, consent to this hypothesis of quartz distortion for an instant. I venture to assert that among millions of pebbles taken from the coal measure, or even from the middle silurian mountains, there cannot be discovered *one* bearing the marks of such distortion; although many of them offer plainly enough the evidences of wear and tear by fracture and the sliding of one stratum of the rock upon the other.

But if the geologist who has lived among unmetamorphosed conglomerates shall enlarge his experience by passing over into such a region as Vermont, where every magnesian rock has become either steatite, serpentine, talc-slate, or dolomite, where every argillaceous clay has been changed into pholarite, or roofing-slate, and every sandstone into quartzite, he may come to listen more patiently to Hitchcock's theorem—that gneiss is nothing more nor less than metamorphosed old conglomerates, wherein the pebbles have been pressed into laminæ composed of sections of the original matrix, themselves also pressed flat and thin. It is a bold assertion. It will demand abundant proof. The microscope will have something to say about it. Certainly it explains the folded veins of quartz in mica-slate, as no other hypothesis has done. It is consistent with the now accepted view of metamorphism by pressure, under the conditions of a moist, low heat. At all events, its ample discussion and copious illustration by Dr. Hitchcock and his son, in the pages of his report of the Geology of the State of Vermont, will remain a part of the classics of our science.

But the daring novelty of this excursion from the beaten track is heightened, when we see it as the short cut of an old man to regain the head of the procession. So far from leading him into isolation from his fellows, his path lay practically parallel with that of the best thinkers of the day. Most men of sixty-seven would tremble to adopt a new hypothesis. How few even at forty-five are able to be tolerant of newer principles! But Hitchcock could follow wherever Bischoff, Senarmont, Delesse, Daubrée, Sorby, and Sterry Hunt could climb. He could give up the igneous origin of granite, the extrusion of molten masses from a planetary necleus of lava, the metamorphism of rocks by a high heat. He was no chamber geologist, and so kept his soul fresh in the open air that no new discovery could take him by surprise. "The opinion is now gaining ground," he writes, "that in many cases, perhaps in nearly all, they are merely stratified rocks, which by heat, or the joint action of heat and water, have lost their stratification and assumed new crystalline forms. They are, in fact, an extreme product of metamorphism." He no longer believed in those semi-theological central fires which no man has seen or can see; in those figments of the imagination, a floating pellicle or wrinkling epidermis to the earth; a universal granite floor, beneath the lowest sediments, azoic and aboriginal; a billowy deep of lava, generating earthquake cataclysms, and ejections of interminable branching dikes of trap and porphyry and syenite—which make the wall charts of Hall and D'Orbigny look now so old-fashioned, and which, in fact, the study of the Laurentian regions of the north, as well as the calculations of physicists, have proved to be mere myths and fables of an olden day. What is to replace them, we know not yet, nor how to do without them in our Structural Geology. The situation of the geological world, just now, is not unlike that of the theological, with its Schenkels and its Colensos, its Ecce Homos and its Leben Jesus. But this is certain—the empire of truth is of perpetual divine right, and cannot be shaken, its motto being, *fiat justitia, ruat cœlum.* What cannot be demonstrated, is fictitious; what has been disproved, is not useful. Better get our first conglomerates from aerolites which we can collect and exhibit in our cabinets than from an aboriginal granite floor which no eye has ever seen, no hammer struck, no foot-rule measured. Better redraw all the anticlinals and synclinals of our cross sections, than gabble about the plications of a crust which seems to be a demonstrated mathematical absurdity. But the fine life-history of him whose eulogy we read to-night tells us a better way. Facts take time. It is not hard for honest folks to wait. All harvests are not for this generation of sowers and reapers. It would be well for all of us, could our enthusiasm, like his, be tempered with conservatism, and our conservatism be fired by an equal expectation of better things to come.

Here, gentlemen of the Academy, I must most unwillingly stop. I cannot give you, as I should like to do, a description of the geological survey of Massachusetts which occupied Dr. Hitchcock from 1830, when he was appointed to it, to 1841, when he published his final report; and again from 1852 almost until his death; nor of the geological survey of Vermont, which he reorganized in 1856, and published in 1861. I cannot even tell you, in the few minutes that I feel are all I have to spare, how greatly we owe to his enlightened exertions that movement of the public mind which about forty years ago produced the early State surveys; nor how much to him should be ascribed the merit of originating, or rather pressing to concreteness, the abstract conception of the desirableness to science in America of some closer personal association of its votaries. To him, more than perhaps to any other man, is due the title of founder of the association of American geologists and naturalists which afterwards assumed the name of the American Association for the Advancement of Science, which will hold its next meeting next week at Buffalo.

Neither can I describe Dr. Hitchcock as a teacher. His Elementary Geology, first published in 1840, reached its thirty-first edition in 1860, and was then rewritten to express the progress which the teacher himself had made. His Geology of the Globe was published in 1853.

Shall I allude to his scientific monuments at Amherst? I need only say to such of you as have not yet beheld them, Go and see what one man can accomplish! All honor to his fellow-workmen there! But what Amherst is, Hitchcock has made it—so says all the world, and what all the world says must be true. He was the master-mind at that centre. Let Amherst erect a statue to him in front of his Museum—a statue of pure, white Vermont marble, for he was an American Christian—a statue lifted high upon a cubical plinth of Quincy granite, for he was a simple-hearted son of Massachusetts—a statue facing Holyoke, for the oblique denudation of its summit, he discovered, and the marvellous beauties of its panorama were his heart's delight. America has reached the time when it needs the idolatry of hero-worship to counteract its excessive tendency to individualization, and its intolerant democracy. And this man is one of America's heroes.

He was, I have said, in some respects even in advance of his age. His theology was gentle, tolerant, and liberal. He was one of the first to recognize the claims to the honest attention of good physical observers which those strange and apparently abnormal physical phenomena make which went at first by the name of mesmerism, and which have been, since then, followed up and obscured by the fanatical and hurtful dishonesties and shameless and tasteless profanities of the modern round table. The evils attendant upon this strange psychological epidemic he was as quick to see as any man, and to recognize also its capacity for warping and marring the youthful science of this land; but no amount of materialistic denunciation from the side of specific science could scare this fearless investigator from confessing his faith in what of fact there was, so far as he could discover it, nor from exercising the function of true science—to wash his facts from the filth in which they were rolled—to set them upon their appropriate shelves in the order of their worth.

He was by nature not a materialist and a scoffer, but a spiritualist and a believer. He believed in immediate creation by the fiat of God. He believed in the Hebrew poem of the creation as a substantial history. But even here he showed himself a man of genuine scientific spirit. He was obliged to interpret, and of course to criticize the Scriptures of his Church. But it is interesting to see how we always in this life return to our first loves. It was in his *later* years that he took up with zeal the defence of Genesis. He was forty-two and forty-four years old when he published, in 1835 and 1837, his pamphlet on the connection of Geology with Revelation, and his pamphlet on the historical and geological deluges. But it was not until 1851, when he was fifty-eight years old, that he gave to the world the first edition of his book, "Religion of Geology and its Connected Sciences," while his book of "Religious Truth Illustrated from Science" did not appear until six years later, when he was sixty-four years old. Of these and other works to effect an impossible harmonization of the developments of modern science with those of the ancient imagination others would speak to better purpose.

By his early personal devotion to field-work—by his long and successful college instruction of successive classes of young men—by the purity and simplicity of his personal nature, which roused no jealousy and excited no suspicion—by his cheerful, modest, but enthusiastic publication at all times of every new fact which he observed, and every new idea which facts observed gave birth to—and by his ready concurrence in every useful scientific enterprise, Edward Hitchcock shines a star of first magnitude in the heaven of American Science.

Do you expect me now to speak of his religion? I am not capable of the task. I hold it true that the Christian is a higher type of man than the Savant. His theology I reckon as of no account: it is his Christianity that crowns his brows with light, and arms his hands with power. He may be a Unitarian, as Edward Hitchcock was in early life, or he may return, as Edward Hitchcock did in after years, to the Orthodox notions of his fathers: it makes less difference than people judge of it. Science will settle all those discussions in good time. But no amount of natural science will stand a man instead of faith in a higher law and an invisible world. No zeal for science will compensate for the lack of temperance, charity, and truth towards our brother man. It was the hold he had upon the Christian heaven that made this man, working among us like a brother, walk among us like a father, trusted and beloved by all. I do not believe in his theology: it savors too much of the central nucleus of fire; it makes our earth-crust too insecure; it is too full of old wives' fables. But we must all believe in his religion, and feel how grandly it ennobled his science, and glorifies his happy memory.

MEMOIR

OF

JAMES MELVILLE GILLIS.

1811–1865.

BY

BENJAMIN APTHORP GOULD.

READ BEFORE THE NATIONAL ACADEMY, JAN. 26, 1866.

BIOGRAPHICAL MEMOIR OF JAMES MELVILLE GILLISS.

MR. PRESIDENT AND GENTLEMEN OF THE ACADEMY:—

THE year which has just elapsed has been more sparing of our number than its predecessors; yet death has taken one from the ranks of the Academy who could ill be spared, and on the 9th of February last the tidings went forth from this capital to all parts of the land, that a great bereavement had come upon the science of America. A month before we had met Gilliss here in the vigor of his manhood, the fulness of his energy, and the manly dignity so characteristic of his bearing.

"O, had it been but told you then
To mark whose lamp was dim,
From out these ranks of active men
Would you have singled him?"

His life has been in some respects its own sufficient record, for its impress has been given and will long remain; yet in other respects the time is not yet come for the full portrayal of his many services to science and to his country,—for these are still too recent for complete recital, and their enumeration and description might tend to impair their best influence. Loyalty to his country, his government, his science, his friends;—stern integrity, unflinching resolve, and earnest piety were the predominant traits of his moral nature. A keen sense of duty, which never permitted to himself those indulgences which his charity readily conceded to others, was blended with exquisite sympathy and kindliness. In his remarkable character the two extremes met of austerity and geniality; but the sternness was for himself, the tenderness was for his fellow-men.

JAMES MELVILLE GILLISS was born in Georgetown, D. C., on the 6th of September, 1811, the oldest son of George and Mary (Melville) Gilliss. His father was in the service of the United States government, and had been so since its transferrence to this city. The family was originally of Scottish origin, but had been in this country for several generations.[1] At the age of fifteen years Gilliss entered the navy as midshipman, and made his first cruise in the "Delaware," under Captain Downes. Returning after an absence of three years, during which he served also in the "Concord" and the "Java," he passed his examinations with honor, and received in 1831 the grade of passed midshipman.

Even at this early age the aspirations which guided his whole career began to manifest their influence. In a letter written long years afterwards to his friend Dr. Gerling of Marburg, he says:—

"Very shortly after I came to Washington for duty as a Passed

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[1] For most of my information regarding Captain Gilliss's ancestry, I am indebted to the Rev. Isaac W. K. Handy, D.D., of Orange Co., Va., who has kindly supplied it to me from the MS. of "The Annals and Memorials of the Handys and their Kindred," soon to be published. The line of descent was as follows:—

A. Thomas Gilliss, an early settler of the Eastern Shore of Maryland and native of Scotland.

B. Capt. Thomas Gilliss, born at Monokin (now Princess Anne), 1668, July 12, married as his third wife Anna, widow of Capt. John Handy, and daughter of Thomas Dashiell.

Children by 3d wife:—

7. Joseph.
8. Sarah (m. Major Thomas Irving).
9. Nelly (m. Capt. George Handy).
10. Anne (m. John Irving).

C. Joseph Gilliss, of Somerset Co., Maryland (7th child of Thomas), married:—

1. Anne, daughter of Col. Isaac Handy.
2. Betty Irving.

Children:—

1. Thomas Handy, b. 1768, d. 1851.
2. Esther (m. Dr. W. Cheney).

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3. Joseph.
4. George.
5. Anna.
6. Sarah (m. —— Polk).
7. Nelly.
8. Eliza.

D. George Gilliss, of Georgetown, D. C. (4th child of Joseph), married ary Melville, their third child being,

E. James Melville Gilliss, born September 6, 1811.

Midshipman, members of Congress were told in my presence, 'There is not an officer of the navy capable to conduct a scientific enterprise.' The charge was intended prejudicially to the service to which I belonged, and was the more humiliating because the speakers were unknown, and defence was not possible. But from that hour no effort has been spared by which the standard of intelligence in the service might be increased and its reputation enhanced."

How much the scientific reputation of the navy may have been directly or indirectly advanced by the exertions of our lost colleague, I will not undertake to estimate; but thirty years have wrought a wondrous change, and the response which the logic of history would furnish to any disparaging remark to-day needs no added encomium of mine.

So keenly was the young officer touched by the assertion, whether true or not, that on the instant he resolved to disprove it in his own person. Such is his account, and from that moment he was wont to date his scientific impulses; yet those who knew him best can hardly believe that to so slight an incident we owe the rousing of his strong powers, and the commencement of that useful scientific career by which he accomplished so much for our country, and which terminated only with his life.

Desiring to perfect his own culture, he applied for leave of absence to prosecute his studies, and in 1833 entered the University of Virginia, resolved, so far as lay in his own power, to bring to his country's service the highest scientific culture attainable. His residence at the University, however, was of less than a year's duration. Excessive study impaired his health, and a severe inflammation of the eyes confined him for many weeks to a dark room. Upon his partial recovery he made a fourth cruise, ending in October, 1835, after which he resumed his studies in Paris, and pursued them there for about six months, before returning to his professional duties.

In the following year, Mr. Gilliss was ordered from Philadelphia, where he had been on duty, to Washington, as assistant to Lieut. (now Commodore) Hitchcock, who was then in charge of the Depot of Charts and Instruments. This institution had been established by the Navy Department six years previous, through the influence of Lieut. (now Admiral) Goldsborough, for the care and distribution of the charts and instruments required by national vessels. Among the duties of the officers was the rating of chronometers. The determination of time was at first made by sextant and circle observations; in 1831 a small transit-instrument was mounted for this purpose; and when in 1833, Lieut. (now Commodore) Wilkes was assigned to its charge, he removed the office to the vicinity of his own residence, about 1200 feet north of the Capitol, erected a small wooden observatory fourteen feet by thirteen, in which he mounted a 4-inch transit-instrument of larger dimensions, lent the office by the Coast Survey. This instrument was made by Troughton, and had a clear aperture of 3¾, with a focal length of 63 inches.

In a very short time after the arrival of Gilliss in Washington, he was placed in full charge of this establishment, and here he made his first astronomical observations, these being at first solely for determining time, like all those of his predecessors. A year later, during the winter of 1837–38, he observed an extensive series of transits of the moon and moon-culminating stars for the determination of longitudes in connection with a survey of Savannah River; but these observations appear never to have been reduced.

At this time he was married to Miss Rebecca Roberts, the daughter of John Roberts, Esq., of Alexandria, D. C., with whom he passed a life of uninterrupted domestic happiness.

For more than twenty-seven years, his interests and cares and aims were hers, and he owed much to her encouragement and sympathy in his intellectual as well as his domestic life.

In 1838 the U. S. Exploring Expedition sailed under the command of Capt. Wilkes. For the purpose of determining differences of longitude by means of moon-culminations, occultations, and eclipses, special instructions were drawn up by him for the observation of these phenomena, and application was specially made by him to the department that Lieut. Gilliss "should not be permitted" to leave the depot during the absence of the expedition. The late Mr. W. C. Bond, who had a transit instrument mounted at his house in Dorchester, was also engaged for the same purpose, the instructions to him and to Gilliss being duplicate. These instructions also contemplated extended magnetic and meteorological observations, and he availed himself of this opportunity to procure a portable 3¼-inch achromatic, equatorially mounted, a variation-transit for use in measuring the magnetic declinations, a balance magnetometer, a dip circle, two clocks, and a chronometer for sidereal time. The instructions from the Secretary of the Navy (Mr. J. K. Paulding) were dated 1838, August 13, and Gilliss's observations began in the very next month. Here commences his astronomical career. Young as he was, he must be considered the first representative of practical astronomy in America. Astronomical observations had been made for a century, it is true. Men, his seniors, now living, and others still not long deceased, had made them before him, and were able to aid him with counsel and even experience. Among these I may mention Hassler, the founder of the Coast Survey, Bache, our own beloved and revered President, whose absence we are mourning, Prof. Bartlett, our honored colleague, Messrs. W. C. Bond, R. T. Paine, Patterson, Olmsted, and Loomis. But it was Gilliss who first in all the land conducted a working observatory, he who first gave his whole time to practical astronomical work, he who first published a volume of observations, first prepared a catalogue of stars, and planned and carried into effect the construction of a working observatory as contrasted with one intended chiefly for purposes of instruction.

"From that time" (September, 1838), says Gilliss,[1] "till the return of the expedition in June, 1842, I observed every culmination of the moon, and every occultation visible at Washington, which occurred between two hours before sunset and two hours after sunrise. The transit was extremely deficient in optical power, and would not define stars smaller than the second magnitude when the sun was two hours above the horizon. The number of transits recorded exceeds 10,000, embracing the moon, planets, and about 1100 stars. The average annual number of culminations of the moon observed was 110, and of lunar occultations about 20."

The difficulties under which he labored, and the zeal with which he pursued his aim, may be inferred from the modest Preface to the volume containing his observations at this little observatory, which were not reduced and published until four years after their completion. It will be borne in mind that these observations of moon-culminating stars constituted but a part of his duties during all this period,—that the instruments and charts

[1] Senate Report No. 114, 28th Congress, 2d Session, p. 65.

of the office were to be cared for, the magnetical and meteorological observations assiduously prosecuted, and many official details to be attended to. Moreover the amount of his astronomical work was understated by him in his report as above cited, inasmuch as his printed volume of observations gives the places of 1248 fixed stars. Of these stars 6823 transits are published, as also 365 transits of the moon, 37 of planets and 84 occultations.

As this volume[1] is now rare, it may not be amiss for me to quote the greater portion of the Preface.

"With but little experience in the manipulation of fixed instruments; without a book relating to the subject in any manner, except 'Pearson's Introduction' and 'Vince's Astronomy,' or an acquaintance in the astronomical world from whom suitable advice could be obtained, literal compliance with the directions of the Department was the only course to be pursued at the commencement of the observations. Indeed, as I had never seen a volume of the annals of European observatories, there could be no reason to suppose they did not embody every requisite to be complied with in recording observations; and it was not until the latter part of 1840 I became aware that the exact state of astronomical science demanded more than a simple record of the transits, after the errors of the instrument had been rectified. For information and counsel on this, as well as other important points, I most respectfully tender my thanks to Rev. Richard Sheepshanks, and to S. C. Walker, Esq., gentlemen whose devotion to and labors in the cause of astronomy have established for them most enviable fame.

"Limited to the Nautical Almanac and the catalogues contained in the volumes mentioned, for observable objects, my attention was early arrested by discrepancies between the clock errors resulting from standard stars and some of those comprised in the list of moon-culminations; discrepancies amounting in several cases to more than two seconds in time, which, being confirmed by the observations of consecutive nights, were consequently altogether beyond the limits of probable errors. Receiv-

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[1] Astronomical Observations made at the Naval Observatory, Washington, under the orders of the Hon. Secretary of the Navy, dated August 13, 1838, by Lt. J. M. Gilliss, U. S. N. Printed by order of the Senate of the U. S., Washington, 1846.

ing about this time, through the kindness of Mr. William Simms, a copy of that *vade mecum* of astronomers, 'The Catalogue of the Royal Astronomical Society,' it occurred to me, that, whilst carrying out the objects of the exploring expedition, the mites which I could add to the data for more correctly locating 'the landmarks of the universe' would not be entirely unworthy of collection; and, with this object in view, I determined henceforward to increase the number of stars to be nightly observed, so as to embrace one in each three and a half to four minutes between the times of transit of the first and last moon-culminating star,—the interval fixed on being the time ordinarily occupied by the transit of one star over all the wires, and setting the finder for its successor. This was all I could hope to accomplish with the means in my power, unless careful estimations of the apparent magnitudes of each star observed should enable me to detect, at the termination of the series, variations in their brightness, or to confirm the degree of lustre already assigned to them.

"All the observations of the volume, excluding a part of those on three dates (as stated in the foot-notes), were made by myself. Absence on two or three days was caused by illness; and it is proper to state, that, with the above exceptions, there was not a visible culmination of the moon which occurred when the sun was less than an hour above the horizon, during the entire period embraced by the observations, or an occultation after the 15th June, 1839, except one, which I did not personally observe, although my residence, till the middle of May, 1839, was two miles distant from the observatory. Earlier in the afternoon or later in the morning than just specified, the transit-instrument would not show stars of the 2–3 magnitude.

"Occupation during the day in attention to the duties originally allotted to the office, and the want of sufficient assistance, prevented any attempt at reduction of the constantly accumulating materials prior to the summer of 1843.

"It remains but for me to express my gratitude that the prosecution of these observations should have resulted in the foundation of a permanent naval observatory, and have obtained for me, though for a brief period, the privilege of association with many of the most distinguished astronomers of the present century."

In describing the results attained, the mention of a serious obstacle ought not to be omitted,—the very inadequate construction of the little building in which the observations were made. The observing slits of the roof of the ten-foot structure which served as his observatory extended only to within three feet of the ridgepole on each side, thus precluding all observations between 26° and 53° north declination, a region which actually includes a portion of the moon's path. This was partially remedied by extending the aperture for about $5\frac{1}{2}°$ on the southern side, which was found to be the utmost that the strength of the edifice permitted, and it was found necessary to compensate even this gain by introducing transverse bars of iron, and nearly one-seventh part, 12 out of 88, of the standard stars of the Nautical Almanac still remained hidden from view.

The magnetic and meteorological observations carried on at the same time by Capt. Gilliss were probably as laborious, and were certainly as conscientiously prosecuted as the astronomical ones. They were subsequently reduced and published, the last volume appearing in the same year with that containing the astronomical results.

I have said that Gilliss's volume of observations was the first one published on our side of the Atlantic, and have shown how, in spite of many and serious obstacles, his conscientious assiduity and unwavering zeal accomplished not only all that his instructions required, but much more than this. It remains to speak in this connection of the character of the observations and their results.

I need not remind you, gentlemen, how many an accomplished practical astronomer lacks that delicacy of the senses, and those other physical powers, by which alone the most refined observations may be attained. Even the best observers have not always the highest qualification in these respects; for a quick ear, a sharp vision, and a delicate touch are by no means all that constitute the highest skill in an observer. The refined methods of observing, the adroit precautions against incidental errors not dependent upon the senses, the ingenious devices for detecting, measuring, and allowing for errors unavoidably incurred, as distinguished from the simple endeavor to avoid them—an endeavor of which the success must necessarily be more restricted by the limits of our senses, however acute, than the attempt at measuring and eliminating these errors is found to be—these are unquestionably the highest characteristics of the practical astronomer; and experience has shown that these will more than compensate for the dimmed eye, the unsteady hand, and the impaired susceptibilities of advancing years. The whole spirit of modern practical astronomy tends in this direction. Never otherwise could that great dictum of the immortal Struve have passed into an astronomical theorem: "Whatever may be seen may be measured." It is by this principle that the modern forms and appliances of the choicest astronomical instruments are regulated, and the modern methods of observation prescribed. No longer are azimuthal errors supposed to be eliminated by adjustment upon a meridian mark, or collimation-errors removed by analogous processes, or clock-rates assumed as constant through protracted intervals of time, nor the graduations of any instruments implicitly relied on for delicate determinations, nor positions based upon the most massive structures assumed to remain constant. The chief effort of the skilful observer of to-day is directed rather to the elimination and measurement than to the avoidance of error; for human sense is but fallible, while human intellect and art are at least a reflex, if not a spark, from the divine altar.

Yet despite all this, it would be folly to attempt to portray the indescribable advantage to an observer which is afforded by delicacy of the senses. Training will do much, but the culture of delicate perceptions must accomplish more than the training of average ones. And it was Gilliss's peculiar privilege to be endowed with a wondrous acuteness of the perceptive powers of eye and ear, as manifested in his astronomical observations. No one at all conversant with observations can examine the printed record, however casually, without a vivid perception of this marked peculiarity. Before it was my privilege to know him and to appreciate his manly truthfulness and scrupulous honor, I once heard another astronomer impugn his observations in this respect. I asked whether the recently published volume of observations were good and creditable to astronomy in America. "Yes," was the reply, "they are very good, too good for Gilliss's reputation. No man could have made such good ones." In fact it is rarely that the record of a transit over the middle thread of his reticule does not accord, to the nearest tenth, with the mean of observations over the five threads.

It is true that *few* men could have made such observations; but happily there are tests, unsuspected then, so searching that cavil is impossible. Not only do the original records exist, in such a form as to preclude any idea that they could have been tampered with—not only have subsequent observations confirmed those of Gilliss and made manifest their high precision—not only was our colleague spared to enrich the annals of astronomy with yet more results of just such quality, in the other hemisphere, but a touchstone exists, potent as Ithuriel's spear. I refer to the so-called personal scale, by which the counting and assortment of the last figures, in a very large number of observations, enables the inquirer to determine the degree of precision of these last figures by the law of probabilities. This searching test was applied to this volume of observations by Prof. Pierce, and with results signally confirming the faith of Gilliss's warmest admirers. In the long list of observers, living and dead, whose results were thus critically and searchingly tested, Gilliss held the second place (aud scarcely second indeed) for the close precision with which his tenths of seconds have been noted—a degree of accuracy only attainable by extreme concentration of energy, and assiduous training superposed upon physical perceptions much more delicate than those of most men. Indeed a moderate amount of scrutiny will detect the growth and development of his powers in this respect from year to year.

Walker tested the same work in a different and more laborious way. He reduced more than a thousand observations over the lateral threads in order to compare their results with those given by the central one, and with similar results. At a meeting of the American Association for the Advancement of Science, he publicly stated, that, after an extensive series of analogous examinations, made for the purpose of deciding the relative weight to be assigned to the results of different observers, he had found transit observations of only one astronomer, Argelander, which manifested equal precision with those of Gilliss.

Such were the observations made by Gilliss in the years 1838–42, beginning at the age of twenty-seven, without previous training other than he had given himself, without astronomical acquaintances, and, what was more than all, without scientific sympathy until the observations had been prosecuted for more than two years.

The printed volume contains nearly 700 octavo pages, comprising the detailed observations of each year, with the details of their reduction, the work of each year being specially referred to the mean equinox of its commencement; and at the close, a General Catalogue of the mean right-ascensions of 1248 stars, formed from these annual tables—together with their precessions, proper motions, and polar distances, derived from the British Association Catalogue, and added for convenience in making one of his own results.

We come now to one of the noblest achievements of Gilliss's life—the construction and equipment of the Naval Observatory. To understand the exact bearing and amount of his services in this connection, it will be well to revert to previous efforts in the same direction, and I will take the liberty of making use, without apology, of a summary of this history, which I prepared a few years since for another purpose.

The claims which science—and especially those departments of scientific inquiry which cannot be prosecuted without the aid of implements inaccessible to most private men—may legitimately make upon a civilized community, if not, indeed, upon its government, are too patent to most thoughtful men, for the want of any proper observatory in the United States thirty years ago not to have been a source of regret, and an occasion for effort to those interested in the intellectual development of our nation. When we consider that not only had England and France led the way, and, for centuries, practically acknowledged the title of the eldest of sciences to national encouragement and support, but that scarcely a principality or petty duchy existed on all the continent of Europe so insignificant, or so poor, that it did not support an astronomical observatory, we cannot but feel astonishment at the unwillingness manifested by the then dominant school of legislators to promote astronomical research by providing some means at the national expense. It was, to be sure, not as a system of wise economy and large policy like that to which this Academy probably owes its origin, and on which its claims to national support might be entitled to acknowledgment—nor even to that still larger and more comprehensive statesmanship, which recognizes in the promotion of scientific research a sure and efficient mode of developing the national resources, both intellectual and material—that the foundation and support of an observatory at government expense was urged. But it was insisted on by its advocates on the ground that the importance of astronomical observations to the world at large, especially their manifest bearing upon commerce, rendered it the bounden duty of the United States, as a mercantile nation, to contribute their part toward those observations and computations for which all other civilized countries strove to do their share, and that a decent national pride should render us unwilling to rely exclusively upon Europe for data indispensable to navigators, even did it not lead us to desire that our republic should emulate her monarchies in the advancement of the highest civilization. Curiously enough, the so-called constitutional arguments brought forward in opposition to such plans did not possess sufficient force to prevent the equipment of that expedition for general geographical exploration to which, through a singular change of circumstances, the establishment of a government observatory was ultimately due. The essential importance of a central observatory for the exploration and survey of our own territory, for the determination of the geographical position of our own ports and inland towns, was also made prominent; yet it seems almost incredible that only thirty years ago, not merely did such arguments as these fail of all effect, but even those men who entertained larger and more elevated views seem not to have thought it worth their while to develop them. But such was the case, and the few instances in which any exertions were made in this direction afford us admirable examples of seed sown upon stony ground—not to allude to another scriptural comparison perhaps yet more appropriate.

The first of these efforts will probably be found in the first message sent to Congress by John Q. Adams, after his inauguration as President of the United States, in March, 1825. In this message "he earnestly recommended the establishment of a National Observatory, as, also, of a Uniform Standard of Weights and Measures, of a Naval Academy, a Nautical Almanac, and a National University. But all these recommendations were treated with neglect by Congress; although time has written a sufficient commentary on their wisdom and foresight. An excellent report on the subject, advocating the views of the President, was made by Mr. C. F. Mercer, chairman of the Committee of the House, to whom, in the ordinary routine, the subject was referred; but the recommendations of the President, and of the Committee, were suffered to lie unnoticed on the tables of both Houses; and it was reserved for the Emperor Nicholas of Russia to follow those counsels which party rancor precluded the Congress of the United States from adopting on the recommendation of their President, and by the establishment of the noblest Observatory of the world to render the capital of his empire a capital of astronomical science."

The first structure in the United States which might claim the name of a fixed Astronomical Observatory was the ill-constructed little edifice of which I have already spoken, 14 feet long, 13 feet broad, and 10 feet high, in which Gilliss industriously labored for nearly four years, making the excellent observations of right-ascension already described, and furnishing the first volume of astronomical observations published in this hemisphere, and probably a more precise record of transits than has ever been made in America by any other person.

In 1838, the year in which Lieutenant Gilliss commenced his observations, a small astronomical structure had been built at the Western Reserve College, in Hudson, Ohio, through the exertions of Professor Elias Loomis, and equipped with a 4-inch equatorial telescope and a 3-inch transit-circle, both of English manufacture. With these Professor Loomis made a number of astronomical observations; but the duties of his office, as teacher, left him little opportunity for continued research.

It was in this same year, 1838, that the money bequeathed by Smithson to found that noble institution, which will render his name immortal, was received by our minister in London. Mr. Adams, then a member of the House of Representatives, again exerted his most strenuous efforts to secure the establishment of an astronomical observatory as a part of the institution. He immediately waited on President Van Buren, and, in a long interview, urged his views of the subject. A few months later, at the call of the Secretary of State, he reduced his views to writing, advocating the application of part of the fund to the establishment of a great observatory, and of a Nautical Almanac. Mr. Van Buren expressed his concurrence with the views, but never acted in the premises.

Indeed, so bitter was the rancor of political partisanship at this time, and so intense the hatred entertained by the then dominant section of the country against Mr. Adams, that, to use the language of his biographer, opposition to the design became identified with party spirit, and to defeat it no language of contempt or of ridicule was omitted by the partisans of General Jackson. In every appropriation which it was apprehended might be converted to its accomplishment, the restriction "and to no other" was carefully inserted. In the second section of an act passed on the 10th July, 1832, providing for the survey of the coasts of the United States, the following limitation was inserted by the Naval Committee: "*Provided, that nothing in this act, or in the act hereby revived, shall be construed to authorize the construction or maintenance of a permanent Astronomical Observatory.*" Yet, at the time of passing this act, it was well understood that a part of the appropriation it contained must necessarily be applied to astronomical observations. And, indeed, I may anticipate the order of this narrative by adding here that when, at last, Congress did appropriate the money for an Astronomical Observatory, and subsequently for its support, it was under a fictitious name, the authors of the laws intending an Astronomical Observatory, and being well aware that the funds would be so applied, but causing the insertion of the proviso in the one case, and of the feigned name in the other, for the purpose of preventing the institution from being attributed to the influence of Mr. Adams.[1]

In 1840, precisely fifteen years after that first message to Congress, in which he had advocated the establishment of a National Observatory by government, Mr. Adams, being Chairman of the Committee on the Smithsonian Fund, made a second report, in which, after recounting all the principal facts connected with the bequest and its acceptance, he again advocated the views which he had so often urged. But while the question was pending, a resolution was passed by the Senate appointing a Joint Committee on the subject of the Smithsonian bequest. The House, in courtesy, concurred, and appointed on its own part the members of the Select Committee, of which Mr. Adams was Chairman, to be members of the Joint Committee. It may readily be imagined that the two portions of the Committee were unable to agree; and it was finally decided that each of the two component parts should present its own report; and, while Mr.

[1] Quincy. Memoir of the Life of J. Q. Adams.

Adams reported[1] a series of resolutions prescribing the investment and management of the fund, and directing that the first appropriation of interest-money should be "applied for the erection of an Astronomical Observatory, and for the various objects incident to such an establishment," Mr. Preston, of South Carolina, the Chairman of the Senate Committee, presented counter-resolutions, containing the provision that no part of the funds should be applied to the erection of an Astronomical Observatory. This report of Mr. Adams is well worthy the perusal of every lover of the exalted science of astronomy, both for the richness of its information and the beauty of its eloquence. In 1840 and 1841, two observatories were established—the first at Philadelphia, by the High School of that city, and the second at West Point, by the United States Military Academy. The former was placed under the direction of the late Sears C. Walker, the other pioneer of practical astronomy in the United States, and of Professor E. O. Kendall; the latter under that of Professor Bartlett. To these astronomers we owe the first introduction into the country of those German instruments which the combined genius of Bessel, Struve, and Argelander, that wondrous triad, together with Fraunhofer, and his gifted co-laborers in the highest fields of optical and mechanical art, had devised and perfected. To these observatories at West Point and Philadelphia, or rather to the ability and assiduity of their directors, working in the hours of relaxation from professional duties, we owe the first important series of astronomical observations made in the United States. It is to the stimulus given by their observations—especially the admirable ones of Mr. Walker, rendered peculiarly valuable by his computations, for which they supplied the material; and to their publications, particularly the able report on European Observatories, presented by Professor Bartlett to the Engineer Department on returning from a journey to Europe for the purpose of ordering instruments—that we are doubtless indebted for much of that public sentiment which, combined with other influences, at last brought about the establishment of the Naval Observatory.

In 1841, after three years of zealous observations, Gilliss obtained authority to import a meridian-circle. This could not

[1] Twenty-sixth Congress, 1st Session, Rep. No. 277.

be erected in the little hut where he was then observing, and he availed himself of the opportunity to urge both upon the Navy Department and upon members of Congress the establishment of a permanent Observatory for the Navy, to be attached to the Depot of Charts and Instruments. Let me quote his own words from his official report after the successful accomplishment of this design.

"As the observations progressed, the unsuitableness of the building, the defects of the transit-instrument, the want of space to erect a permanent circle, and the absolute necessity of rebuilding the observatory in use, became each day more urgent, and, at my earnest solicitation, the Commissioners of the Navy recommended an appropriation for a permanent establishment in December, 1841. Even this, however, was not accomplished without difficulty. But the efforts of the honorable Secretary to advance science, and more especially those branches of it in which the Navy is interested, are well known to the country; and immediately appreciating its importance, he brought this subject before Congress in his report to the President of December, 1841.

"Much delay occurred with the Naval Committees in Congress. The Hon. Francis Mallory, to whom it was referred by the House Committee, espoused the cause warmly, but the majority kept aloof from the depot (although so near) until the entire winter passed away. Finally, on the 15th March, 1842, I succeeded in persuading the only member of the committee who was skeptical to visit the observatory, and on that very day a unanimous report and bill were presented to the House of Representatives. Believing the chances of success would be greater if a bill could be passed by the Senate, by the advice of Mr. Mallory, I waited on the Naval Committee of the Senate, but my entreaties for a personal inspection of our wants were put off from time to time. The question was probably decided by an astronomical event.

"At a meeting of the National Institute, at which the Hon. William C. Preston was present, I gave notice of having found Encke's comet with the 3½ feet achromatic, the comet being then near its perihelion. A few days subsequently, I made what was intended to be a last visit to the chairman of the Senate Committee, and found Mr. Preston with him. As soon as I began the conversation about the little observatory, Mr. Preston inquired whether I had not given the notice of the comet at the Institute, and immediately volunteered, 'I will do all I can to help you.' Within a week, a bill was passed by the Senate.

"It is hardly necessary to trace its progress in the House. A majority was known to be favorable, but its number on the calendar, and the opposition of one or two members, were likely to prevent action upon it; and that it did receive the sanction of the House of Representatives at the last hour of the session of 1841–42, the Navy is indebted to the untiring exertions of Dr. Mallory."

Meanwhile Mr. Adams, on the 15th April, 1842, had presented yet a third report from the committee on the Smithsonian fund in the form of a bill, providing for its administration on the same principles which he had advocated in former years, and directed that the income already accrued should be invested as a capital, and its interest applied to the construction and maintenance of an Astronomical Observatory. The bill failed; for, as Mr. Adams's biographer remarks, "there was no purpose on which the predominating party were more fixed than to prevent the gratification of Mr. Adams in this well-known cherished wish of his heart." Yet an Observatory, under a feigned name, and restricted to the Navy Department instead of being made a national institution, was established by act of that very Congress at that very session, without a division, or indeed any opposition in either House; and four years later the Smithsonian Institution was organized essentially on the basis so often urged by him, although omitting the Observatory element, which was then no longer desirable, inasmuch as the end had been obtained by other means.[1]

The bill introduced by the Naval Committee of the House of Representatives was read twice and disposed of by reference to the Committee of the Whole on the State of the Union. But on the 23d of June, a bill identical in its language with the one thus laid to rest was introduced in the Senate, as related by Lieutenant Gilliss in the extract which I have presented from his report. This passed through the several stages of legislation in due order, without hindrance or objection; went to the House on the 30th July; was referred to the same committee as before; but as a

[1] Gilliss's Report, p. 65.

Senate bill was treated with courtesy. It was reported back without discussion, passed by the House without debate, and on the 31st August, 1842, became a law.

Thus was established the present Naval Observatory, owing, like all progressive steps in our country, at least, to the combination of many influences, and the gradual education of the community by a few leading intellects—yet how large a share in the work was due to Gilliss, this history will show. His useful observations, together with his excellent administration of the affairs of the Depot of Charts and Instruments, had won the confidence of his official superiors, and impressed all whom he could induce to see what he was doing. To his immediate influence must be attributed the official recommendations of the Naval Commission in December, 1841; that of the Secretary of the Navy in the same month; the unanimous presentation of a bill in its favor by the Naval Committee of the House, after much reluctance, and in spite of strong political prejudice against this very measure under another name; the winning to his views of the identical Senator who had presented resolutions concerning the Smithsonian fund, "providing that no part of the funds should be applied to the erection of an Astronomical Observatory," and that persistent advocacy which culminated in the final passage of the bill on the last day of August, 1842, without discussion and without a division.

Nine days later the Secretary of the Navy, "taking the Report of the Naval Committee, which accompanied the [House] bill, as the exponent of the will of Congress," assigned to Lieutenant Gilliss the duty of preparing the plans for a building and arranging for the instruments. How well he did his work I need not tell you.

After consulting those Americans most conversant with astronomical subjects, he visited Europe to obtain the counsel of foreign astronomers, and to make himself acquainted by personal inspection with the latest improvements in the construction of astronomical and magnetic implements. In March, 1843, he returned home, having ordered the instruments under authority from the Secretary of the Navy, and began the erection of the Observatory. The building was completed, the instruments mounted and essentially adjusted, and a library procured within eighteen months.

On the 7th February, 1845, Gilliss presented a detailed final report of his labors, which is published as Senate Document No. 114, 28th Congress, 2d Session. It contains full descriptions, with minute drawings, of the instruments, and suggestions as to the ends to which they might be most usefully devoted, and it is a curious fact that these instruments are essentially the same that, after the lapse of 21 years, are still in active and successful employment. The only important change is the disuse and removal (by himself) of the Ertel Circle—obtained by him while still at the little box on Capitol Hill, and subsequently mounted at the new Observatory—in order to make room for the magnificent meridian-circle also ordered by him, but which it was never his privilege to look upon. This noble instrument, purchased by the Navy Department under authority of the present Superintendent, then Chief of the appropriate Bureau, is now in working condition, and offers rich promise of contributions alike useful and honorable to science.

The great work was thus accomplished. The first working American Observatory had been built—stimulating to quick emulation in the Observatory at Cambridge, and so on in the numerous other similar institutions which now ornament our land. Who should direct its activity? Lieutenant Gilliss had brought about its existence, had planned it, selected and ordered the instruments, superintended the construction of the building, mounted and adjusted the instruments, and at the close of September, 1844, reported the work done and the Observatory ready for occupation. No breath of scandal had ever sullied his fame. He was the sole working astronomer in the nation. His work had met the commendation of astronomers everywhere, so far as they had had opportunity to become acquainted with it.

It was not Gilliss who was assigned to its superintendence. But, on the 1st October, orders to assume the charge of this noble institution were issued by Hon. John Y. Mason, then Secretary of the Navy, to Lieutenant Matthew F. Maury, a young officer without scientific education or experience, and with small scientific pretensions. A corps of three lieutenants, six midshipmen, and a machinist was assigned him, and within the year four more lieutenants and three naval professors were added to this corps, in addition to the all-important, but unhappily very temporary services of the gifted and enthusiastic Walker. Surely with such an organization we might have looked for more than we received; especially when we remember that Walker, Hubbard, Coffin, Ferguson, Keith, Yarnall were among its members. Honor to their names for what they did accomplish.

The influences which prompted this appointment and the intensely mortifying treatment of Gilliss seem to have been no very recondite ones, and can be readily imagined by any of you—for it needs but a five years' memory to recall those ancient days; yet never in the course of fifteen years of friendship, an unrestricted intercourse, and a close intimacy, did I hear one word of even pardonable bitterness, either concerning this severe disappointment, or the neglect of astronomy by the officers to whom the Observatory had been assigned. "It was hard," he would say, "but an officer must obey orders and not find fault with them." On the other subject he ever preserved a dignified reticence, and it is my firm belief that in his freest utterances he never spoke one word expressive of the sentiments which we may naturally suppose him to have entertained.

From February, 1845, to July, 1846, Gilliss was occupied with the preparation of his observations for the press, as has been already mentioned, and at the close of this work he was assigned to duty upon the Coast Survey under Professor Bache. While on this service he reduced for the use of the Survey the entire series of moon-culminations previously observed and published by him. Fifteen manuscript folio volumes in the archives of the Survey contain this valuable work, the subsequent discussion of which by Walker, and still later by Peirce, led to the investigations by these geometers into the relative accuracy of Gilliss's observations, concerning which I have already spoken.

In May, 1847, Dr. Gerling, the eminent mathematician of Marburg, published a memoir, calling the attention of astronomers to the fact that the universally adopted value of the solar parallax depended solely upon observations of the transits of Venus in 1761 and 1769; and that, although the materials afforded by the observations then made had doubtless been exhausted by the labor and skill with which Encke had deduced the value since adopted by astronomers, yet a constant so important as this, which affords directly or indirectly the sole unit for the determination of all celestial distances, should not be subject to the possible uncertainties of any one method. Especially was it unfortunate that the only method employed depended upon a phenomenon which recurred, doubly to be sure, yet only at intervals of more than a century; and which would not again take place until after the lapse of more than a quarter of that period.

The combination of observations of Mars at opposition, made from terrestrial stations widely differing in latitude, had been frequently suggested; but Dr. Gerling advocated especially the similar employment of observations of Venus at inferior conjunction, and especially when at, or near, the stationary points, and of oppositions of Mars. His conviction in favor of this method rested principally on the consideration that, whereas, in transits of Venus, the quantity to be determined is the difference between the parallax of the planet and that of the sun—the other methods yield the planet's parallax at once—the element directly deducible bearing to the solar parallax the following ratios:—

At transits of Venus . .	2.57
At oppositions of Mars . .	1.92 on the average.
" " " " . .	2.74 in extremely favorable cases.
Inf. conjunctions of Venus .	3.57
Stationary positions of Venus	2.94

Thus the observations of Venus promised to yield a better determination of the solar parallax than any oppositions of Mars; and those at the stationary or turning points of her apparent path, a result surpassing in accuracy that from the average of these oppositions by about $\frac{2}{7}$ of its whole amount. The natural objection that the conjunctions of Venus must be observed by day, thus dispensing with the advantage of micrometer comparisons, and requiring meridian observations at midday, was recognized by Dr. Gerling, but the excellence and power of the newer meridian instruments were cited as compensating for this serious disadvantage. The observations during the stationary period were, however, chiefly urged.

Before the publication of this memoir, in which the subject was discussed at very considerable length, Dr. Gerling had, in April of the same year (1847), written to Gilliss, in acknowledgment of his volume of observations, and, in his letter of thanks, gave some account of his proposition.

"I am of opinion," said he, "that astronomers act unwisely in considering the solar parallax deduced from the transits of Venus in 1761 and 1769 sufficiently correct, and do not avail themselves of more modern methods of observation, for the purpose of gradually acquiring more accurate knowledge of it. It is true, indeed, that the oppositions of Mars were long ago proposed for this purpose; but I am not aware that any effective use has been made of them since 1751, although the Nautical Almanac has regularly furnished an ephemeris. There is, however, a *third* method, which presented itself to me some time ago, and I cannot comprehend why it should have been so entirely neglected. I mean, by observations of Venus during the period of its retrograde motion, and, more especially, when the planet is stationary.

"The delicate and faint crescent form of Venus, at the conjunctions, offers excellent opportunities for observation; and from what I have been able to accomplish with my small instrument, I have every reason to believe that most excellent results are obtainable with meridian instruments, at observatories in opposite hemispheres, but lying nearly under the same meridian. Furthermore, at that time, Venus is almost twice as near to the earth as is Mars when in opposition, and observations upon it have the very important advantage that it is not absolutely essential they should be simultaneous, or nearly simultaneous. Again, when the planet is stationary, the observations of one meridian may be readily referred to another by interpolation, without risk of error, and, at this time, it is much nearer to the earth than Mars can be in the most favorable case. Finally—the distance of the planet from the sun being about 29°—micrometrical may be combined with meridional observations. In my opinion, then, it should be our object to multiply meridian observations of Venus about the periods when it is stationary, and endeavor to obtain micrometrical measurements from all parts of the earth; more especially from voyagers."

After a summary of his views, Dr. Gerling continued: "The preceding synopsis of my paper will, I hope, reach you in print after a while. Meantime, I beg you will examine the subject, and, should you coincide in my views, I trust you will interest American astronomers as far as you can, for I flatter myself that observations will be instituted this year at European observatories; and, indeed, I am sure that a greater number of accurate meridian observations are likely to be made during the months of September, October, and November than is common. For the results and success of 1847, it is much to be desired that the few delicate meridian instruments in the southern hemisphere should be brought to co-operate with us; and this, perhaps, it is in your power to facilitate. Of equal consequence will be micrometer observations from the same section of the globe; but as the latter require no permanent observatory, and only a chronometer, a telescope fitted with a micrometer, and a knowledge of the neighboring stars, such observations may well be made by travellers. Whether there will remain time prior to the eastern period for the necessary instruction of voyagers to the southern hemisphere, I am not able to determine."

"This letter," says Gilliss, in the history of his expeditions, "bears date 17th of April, but was not received until the early part of July, and the next eastern stationary term was to occur in September. On conference with the late able astronomer, Professor S. C. Walker, he suggested the immediate publication of the letter, as the mode most expeditious of making it generally known, and, in accordance with his advice, printed copies of a translation were forwarded to all the astronomers and observatories of the United States, with as little delay as possible. There was too little time in which to perfect arrangements for more extended co-operation at that conjunction, and Dr. Gerling was shortly notified that the distribution of his letter was probably all that I should be able to do in the work for 1847. But, to prove my interest in the prosecution of the problem to its solution, I then proposed an expedition to Chile, to observe the planet near its stationary terms and opposition, in 1849, should my views receive encouragement from astronomers to justify such an undertaking. Nearly on the same meridian as Washington is the island of Chilóe—a place of considerable trade with the nearer ports, and occasionally visited by American whale-ships. At all events, it was accessible without much difficulty, and I hoped to be able to induce the government to send me there, proposing to leave the United States in time to reach the island by the middle of March of that year, at latest. To avoid expense, which it was supposed would prove the first and main obstacle, I contemplated only one assistant, who, like myself, would be an officer of the Navy, and in the receipt of pay, whether abroad or at home, and would take instruments already belonging to, or under control of, the government. I proposed Chilóe, because it was the point farthest south on this continent at which a lengthened winter residence could be endured, in exposure, without incurring an outlay that might prove a serious impediment, and because I thought that a passage to it could be obtained in a whale-ship from one of our northern ports. It being inhabited by a civilized and most hospitable people, would tend to render a residence of five or six months, in the latter part of the autumn and winter, not altogether uncomfortable. Its distance is about 5000 miles, due south from Washington; and a comparison of the observations I proposed to make there, with those to be obtained at the Washington Observatory, would give us a determination of the parallax from data wholly American. This last reason I hoped would benefit me, should it be necessary to seek the interposition of Congress."

Then commenced a series of efforts, prosecuted with the well-known energy of our lamented colleague, to prepare judicious plans and to interest both astronomers and lawgivers in the proposed enterprise. "Remembering," said he, in a letter to Gerling, in November following, "the vast outlays Europe has encountered in efforts for the faithful solution of this very problem, as well as in other hundreds of scientific enterprises, and the fact that America, which participates so largely in the benefits derived from the labors of astronomers, has hitherto contributed so trifling an amount to the common stock, I am the more keenly sensible of the noble opportunity now within our grasp to present the world, from our own continent as a base, the dimensions of our common system. . . . . There is but one perceptible obstacle—pecuniary outlay—yet when its very inconsiderable amount is contrasted with the grandeur and importance of the object to be attained, I cannot bring myself to believe that this objection will be suffered to weigh, and I therefore repeat the remark made in my former letter—give the proposition the encouragement of scientific men, and I stand pledged for its successful equipment. At all events, regarding it as a possible attainment only, two questions present themselves for consideration, and it is time they were discussed: first, Is the locality proposed (Chilóe) the best which can be selected for the contemplated object? And second, Will the instruments which have been specified to you permit the accomplishment of that object in the most satisfactory or desirable manner?"

To the careful examination of these all-important questions Gilliss addressed himself with zeal, entering into correspondence on the subject with American and foreign astronomers, and gathering information and counsel from every possible quarter. He soon found that the climate of Chilóe was ill-adapted to his purposes, and that the better climate of Valparaiso would in all probability more than compensate for the diminished length of base which it would entail. Some disadvantage arose from the eastwardly trend of the coast farther north, which would carry the observer to the eastward of Washington; but this he over-ruled as a minor objection, "more especially as we have other observatories at Philadelphia, West Point, and Cambridge, whose equipments justify the expectation that they will take part in the observations; and there is but one to the westward of us at all likely to co-operate, viz., at Hudson, Ohio."

Encouragements soon began to arrive from the other side of the Atlantic. Gauss and Encke contributed the influence of their great names, and Bache, Peirce, and Walker added their endorsements to the plan. Resolutions of approval and recommendation were passed by the American Philosophical Society, of Philadelphia, and the American Academy of Arts and Sciences, of Boston; and each of these bodies, then the leading scientific tribunals of the land, appointed a committee to co-operate in furtherance of the undertaking. The Secretary of the Navy referred the matter to the action of Congress; and within a fortnight a report was made by the Hon. F. P. Stanton, of Tennessee, chairman of the Naval Committee, cordially approving of the plan. Gilliss had pledged himself that if the Navy Department would furnish the apparatus already within its control, and assistance from the officers under its direction, the total expenses of every kind for the expedition, exclusive of instruments, should not exceed $5000. The Naval Committee reported an amendment to their bill, appropriating this sum, and giving the requisite authority to the Secretary of the Navy. The clause was sanctioned by both Houses of Congress, and the bill containing it was approved by the President on the 3d of August, 1848. Preparatory orders were at once issued by the Secretary, containing all needful authority for making the preliminary arrangements.

Before a year had elapsed, the programme had been matured, the formal concurrence of the committees of the two learned societies obtained, an equatorial telescope and a meridian-circle ordered and constructed, and Gilliss had reported to the Navy Department that the instruments and other portions of the equipment essential to the proposed observations were on their way to Chile, in charge of the officers assigned by the Department as assistants. Not a fortnight more than the year had passed when Gilliss himself was on his way to Valparaiso, where he arrived by the way of Panama, in advance of the ship containing the instruments and his assistants.

The detailed account of the organization of the expedition is very interesting, and may be found presented at length by Gilliss himself, in the third volume of the Results of the Expedition. The limits of this notice preclude any more minute description; but the whole constitutes a most interesting chapter in the history of science in America, and one no less important in its indirect influence than in its direct results. It was one of the earliest instances, if not the first, of deference, by the legislative and executive authorities of the nation, to the views of the organized representatives of science within its borders. Rarely before had they been consulted when the weightiest scientific interests were at stake, and almost as rarely had any formal expression of their convictions, however unanimous, availed to guide the scientific policy of the nation. It was moreover the occasion of the first order to an American artist for a telescope of any considerable dimensions, and to the truly patriotic spirit shown by Gilliss on that occasion, at the instance of our colleague, Mr. Rutherfurd, whose efforts in that direction are so familiar to us all, may unquestionably be attributed much of that subsequent development of instrumental art of which we are now so proud, and which has already given such distinction to the names of Fitz, Spencer, Würdemann, Clark, Tolles, and others, all happily yet remaining to us except the first-named—the pioneer of all. Although well aware of the danger of too much detail, I cannot refrain from giving the history of this first large American Equatorial. The five-foot telescope purchased for the exploring expedition, and upon which Gilliss has depended for his observations, was found, to his dismay and embarrassment, to have been stored in a position exposed to the extremes of temperature and moisture, which had seriously, if not fatally injured the object glass. Already the Fox's deflector had been found to be hopelessly injured, and the declinometer to have been given to a mixed commission for surveys in California. But in these difficulties the Smithsonian Institution, although scarcely more than organized, came to his relief. Professor Henry offered a seismometer and a complete meteorological outfit, and subsequently authorized the purchase, at the expense of the Institution, of a complete set of portable instruments for magnetic determinations. But where in this unforeseen emergency to look for the telescope, the indispensable implement for the proposed observations, became a question of the most serious moment. Nearly one-half of the appropriation was already pledged for the meridian-circle ordered from Berlin, and $1000 at the least would be needed for the piers, buildings, etc.

To the honor of the Smithsonian Institution, this admirable organization came again to Gilliss's succor. Although all its available funds were in demand for current expenses, and for the erection of the expensive building, then slowly going on, so that any immediate appropriation of the requisite amount was out of the question, the Regents, at the instance of Professor Henry, manifested a deep interest in the undertaking, and at last offered the credit of the Institution by authorizing the purchase of an equatorial telescope of 6½ inches aperture, provided it could be obtained at a stated price, with interest, on a credit of three years.

Let me continue in Gilliss's own words—"No importer to whom application was made was willing to order one from Germany on such terms. Messrs. Merz, the successors to Fraunhofer, at first declined selling without the cash; indeed their ordinary custom is to demand one-half the price in advance; and the only maker in the United States likely to execute properly the mechanical portions of so large an instrument refused to accept the offer. Just as I had made arrangements to borrow on my own account the sum charged by Messrs. Merz, and import an equatorial from them, Professor Henry authorized me to increase the offer to Mr. Young, of Philadelphia, and eventually a contract was concluded with him, on behalf of the Smithsonian Institution, the right being reserved to me to procure the object-glass and micrometer from such artists as might be preferred.

"About this time notice was published by Mr. Rutherfurd, in Silliman's Journal, of the performance of an object-glass made from imported materials by Mr. Henry Fitz, an optician at New York. Learning that several other lenses had been perfected by the same artist, I determined to examine them all, and then confer with Messrs. Bache, Peirce, and Walker. To be brief, the examination and conference resulted in an order to Fitz to grind a lens from Guinand's glass, to be of the same diameter (six French inches) as that of the telescope at the High School Observatory in Philadelphia, and to forward it to Professor Kendall. If he and other competent judges should pronounce it as good, *in every respect*, as the High School lens, it would be purchased at the Munich price, $500. If inferior, we should have the right to retain and use it, free of cost, until another could be imported from Bavaria.

"Between the date of the order, November 27th, and the time that the tube was ready, April 15, 1849, Mr. Fitz prepared three lenses of that size. Veins developed themselves in one, only after it had been polished; and a second proved scarcely less objectionable in its crystallization. Of the third submitted for trial, Professor Kendall wrote to me, May 1: 'I had the pleasure of making trial of the Fitz object-glass last evening, and was highly gratified with the result. I compared it with ours upon the moon, Jupiter, several double stars, and the bright star Vega, with its companion, using a variety of powers, and it is my opinion that Mr. Fitz has fully accomplished all that he undertook to perform. From this trial I am unable to pronounce which is the better glass. The Fraunhofer did nothing which was not as well done by the Fitz glass. . . . . Indeed, we are all delighted with his success, and I am fully persuaded that between this and one you might order from Merz the chances would be decidedly in favor of the former.'

"Gratification is a feeble word to express my pleasure at the success of the American optician, for I could not but think this first *Yankee* telescope of considerable size marked an era in the progress of mechanical science in our country, for which I hoped future astronomers would render due credit to the expedition. That Mr. Fitz was thoroughly competent to figure and polish, I was fully convinced, on examining the object-glasses previously made, and my only regret was that he could not forthwith undertake the whole task, and begin by manufacturing his own glass.

But he had genius, and nothing would be more likely to stimulate him to undertake it than the success just met with.

"Thus, through the assistance of others, the expedition would be most efficiently equipped; and the support of the Smithsonian Institution, at a very trying period, will always be remembered with the sincerest gratitude."

Two passed-midshipmen, Messrs. Archibald MacRae and Henry C. Hunter, were detailed as assistants, and a young civilian appointed as "Captain's clerk," and thus the expedition was equipped. Before their departure they were stationed for a short time at the Observatory, for instruction by the officers in charge of the instruments, and employed in selecting stars to be designated in advance as objects of comparison. Lithographed charts exhibiting the apparent paths of both Venus and Mars during the period of the proposed observations in the years 1849–52, were sent to all the northern observatories, since the observations for parallax would be available only when combined with corresponding observations in the Northern Hemisphere. And inasmuch as the co-operation of all other institutions would be matters of favor or of scientific zeal, special instructions were issued by the Secretary of the Navy to Lieutenant Maury to cause the requisite observations to be made at the Naval Observatory.

A circular was also prepared by Lieutenant Maury, and distributed to the various observatories of the world, describing the expedition, asking for their co-operation, and requesting that the results be sent annually to him at the Washington Observatory.

The precise place of observation was left to be decided upon Gilliss's arrival in Chile, the only limits determined in advance being the parallel of Valparaiso and Concepcion. It was not till after his arrival in Chile that the city of Santiago was fixed upon, as combining the greatest number of advantages; and there, upon Santa Lucia, a small porphyritic knoll in the eastern quarter of the city, the observatory was erected, which had previously been constructed in Washington.

The Chilian government received the expedition with a cordial hospitality, placing at his disposal any unoccupied public ground, admitting free of duty all the effects of the officers as well as the equipments of the expedition, and from first to last facilitating the enterprise by every means in their power. On the 6th December, 1849, the equatorial was in position, on the 10th the series of observations of Mars was commenced, and it was continued for the fifty-two remaining nights which had been designated in the programme, with the loss of only four, on which the weather was unfavorable. Early in February the circle was ready for use, and a series of zone observations was commenced with it at 15° from the pole—working toward the zenith on successive nights in belts 24′ wide, until compelled to return below again in order to connect in right ascension. "We were always occupied," says Gilliss, "from five to six, and sometimes more, hours. Lieutenant MacRae and myself devoted alternate nights to these observations, very rarely having relief by clouds until after April 21. Indeed, between Feb. 4th and that date, seventy-six nights, there were only four of them obscure. The rains of latter autumn and winter came none too soon for us."

Meantime, at the application of the Minister of Public Instruction, three young Chilians were instructed in astronomy and the use of instruments; and magnetic and meteorological observations were systematically carried on. Mr. Hunter, having been injured early in January by being thrown from a horse, was obliged to return to the United States, and his place was supplied by Passed-midshipman S. L. Phelps, the same who has since, as Lieutenant-Commander, rendered such essential service to the country in naval operations upon the Mississippi, and other western rivers.

An accident to one of the micrometer-screws of the circle rendering the simultaneous labor of both assistants necessary at the zones, their duties were fixed for each alternate night, while Gilliss himself employed the intermediate ones in examining such of LaCaille's stars between the zenith and the pole as had never been twice observed. The pages of the astronomical periodicals of that time bear witness to the effectiveness of his scrutiny, by the record of many hundred errors detected in the Catalogue of LaCaille. On the reception in June of new micrometer-screws from the makers in Berlin, the original system of observations was resumed. During the series of observations of Venus, Gilliss records several occasions when the cusps of Venus could be distinguished by the unassisted eye.

I will not dwell further upon the details of the observations, for they are fully described in the magnificent volumes containing the results of the expedition. Let me simply sum up the work accomplished. Between the 6th December, 1849, and the 13th

September, 1852, series of micrometric comparisons of Mars were made on forty-six days during the first, and ninety-three days during the second opposition, and micrometric comparisons of Venus on fifty-one days during the first, and twenty-seven days during the second inferior conjunctions; the observations on each day being continued through several hours, whenever the sky permitted, and the work being executed with the same delicacy and care which had characterized those earlier transit-observations on Capitol Hill in this city. In addition to this, very much else had been done; but these grand series of observations, executed in precise conformity to the programme laid down, warranted the confidence that his devotion had not been in vain, and that the problem of the parallax would be solved. His two hundred and seventeen series of observations extended over nearly three years;—if northern observations had accomplished half as much in correspondent observations, the question must be decided, and the celestial unit of measure determined with new precision.

What shall I say, Gentlemen of the Academy, of Gilliss's emotions, when, after returning from his long absence to combine and discuss the result of his five years' labor, he found the following correspondent observations awaiting him?

From the Washington Observatory—eleven of Mars, of which six were recorded as wholly, and three others as partially unsatisfactory, and eight of Venus, two of which were noted as bad. From the Cambridge Observatory—five of Mars, of which four were of one limb only. From the Greenwich Observatory—four of Mars, three of them being designated as not good. From all northern observatories, none. His expedition was fruitless, so far as his primary object was concerned, but the consciousness was his, that he had done his duty.

He caused his results to be elaborated, thoroughly discussed, and all possible observations in the Northern and Southern Hemispheres to be collected and combined. No toil was spared in this work; and the recollection of the painful struggle to attain, through punctiliousness of computation, what had been hoped for from abundance and thoroughness of observations, is yet among the most vivid within the range of my memory. But it was in vain. The processes of reduction, the reference to approximate ephemerides, the determination of the comparison-stars, are all on record, and it will be for the future historian, when the true values are established beyond question, to decide whether a better determination can be elicited from the materials provided.

The final results attained were—that from the second opposition of Mars, as also from either conjunction of Venus, no tolerably probable result could be deduced, by reason of the almost total lack of observations; and that whatever result was deducible must be from the first Mars-opposition alone. The materials here too were entirely inadequate, though in comparison with those for the three other series they seemed large; but on closer scrutiny a great portion of them proved not to have been made with the needful care. The only result to be deduced was altogether at variance with that which subsequent investigations have rendered probable.

Fortunately for science, and happily for Gilliss's own consciousness, his observations were not limited to those which it was his special duty to make. Even these on Mars and Venus, which failed of yielding their deserved fruit in affording those data which they were instituted to obtain, are yet of priceless value in the means which they afford, and which will doubtless soon be made useful, for improving our knowledge of the orbits of our two neighboring planets.

Among other astronomical fruits of the expedition to Chile I may mention the following: 7000 meridian observations of 2000 stars, chiefly the standard stars used for determining the errors of instrumental adjustment, and the LaCaille stars already mentioned. These, with their instrumental and tabular reductions, and a resultant catalogue of their mean places for the equinox of 1850.0, form a part of Vol. IV. of the series of the results of the expedition. The remainder consists of observations of Mars and Venus not included in the Parallax volume, and observations of the moon and moon-culminating stars. This volume was left ready for the press at Gilliss's death; and his distinguished successor, Admiral Davis, gives me the gratifying information that he proposes now to strike off and bind up the catalogue by itself, on account of its special utility to astronomers.

Equal, if indeed not superior, in value to these are the Zones, comprising more than 33,000 observations of about 23,000 stars within $24\frac{1}{5}°$ of the South Pole. These comprise stars to the tenth magnitude inclusive, more than five-sixths of which, or about 20,000, had not before been observed. These will constitute the fifth volume, which will contain about 1200 quarto pages. The reduction of the declinations has already been essentially completed, and Admiral Davis, under whose charge the work is now placed, estimates that two years' more labor with the present force will prepare it for the press. I need not say with what satisfaction the publication will be welcomed by astronomers throughout the world.

An unforeseen and peculiar obstacle was encountered in the large azimuthal motion of the hill of Santa Lucia, which seemed to undergo a certain amount of rotation, alternating in direction as the scorching rays of the sun by day, or the frigid emanations of the near Andes by night, alternately exerted their maximum effect. This phenomenon seems to have been not only greater in degree, but entirely different in some respects from that other analogous phenomenon of diurnal azimuthal fluctuation, which there is now reason to believe very general, and of which I have spoken on other occasions. Add to this the earthquakes, of which he recorded one hundred and twenty-four observations during the three years of his sojourn in Santiago, and which inevitably destroyed or changed the adjustments of the instruments, the permanent or temporary loss of assistance on several occasions, and the exhausting nature of the observations, continued with such unfailing assiduity through seasons at once so cloudless and so enervating, and you may form some estimate of the effort and energy implied. Such are the astronomical results of this most honorable and useful expedition; yet these constitute by no means all the information it collected.

The observations on earthquakes are most valuable and extensive, comprising not merely those made under Gilliss's immediate direction, but others also, instigated or collected by him, of the same phenomena at other places than Santiago, during his stay in Chile. Among these is an admirable series, not less complete than his own, observed by Señor Troncoso at La Serena, the capital of the province of Coquimbo, about 250 miles to the north of Santiago. These, and a collection of the accounts of the chief Chilian earthquakes on record, are included in his first volume, and warranted in Gilliss's opinion sundry important deductions, the chief of which, apart from those of a purely local nature, are: That there are no permanent centres of disturbance, the apparent direction of the vibrations varying at each occurrence. That a large proportion of the tremors are neither undulations nor vibrations, but rather rapid vertical displacements of the crust of the earth, almost, if not absolutely simultaneous over the disturbed district. And finally, the very curious one, that the season of the year seems to exert some influence—the average monthly shocks at Santiago during thirty-five consecutive months being 13⅜ for April, while it reached in no other month so large a number as 14½, and similarly at La Serena, the average number during twenty-eight months being fifteen for November, eight for December, and for the mean of the other months less than four.

The barometer and thermometer were recorded seven times in the twenty-four hours for the whole thirty-five months, and hourly one day in each month. On three days in each month, one of these being the regular "term-day," extended systematic observations of direction and intensity of terrestrial magnetism were carried on; and on the first of each month, during preappointed hours, the fluctuations of the magnetic declination were watched, simultaneously with corresponding observations by the Coast Survey on the Atlantic and Pacific coasts of the United States, to discover whether these fluctuations showed indications of synchronism in the two hemispheres. The last of the six quarto volumes which record the results of the expedition is already published, and devoted to the meteorological and magnetic observations, and their tabular discussion.

The first volume of this series contains an elaborate treatise upon the physical and social characteristics of Chile, its commerce and its resources. The second volume begins with the narration of Lieutenant MacRae of a journey homeward and back across the Andes and Pampas. After the completion of the magnetic observations in Chile, they were placed in charge of Lieutenant MacRae, who was instructed to carry them across the Andes and the Argentine Territory, returning home by the way of Buenos Ayres, making regular observations on his way for determining elevations, geographical positions, magnetic and meteorological data, for each 3000 feet of ascent and descent, and for each hundred miles of longitude; and collecting at the same time such other geographical and statistical data as he could. These instructions were well carried out by Lieutenant MacRae, but his mountain-barometer having been broken on the way, and his chronometers so much injured as to impair his reliance on them for longitudes, he offered on his return to retrace the journey at his own expense, and repeat the observations, provided a new set of instruments could be supplied. This was at once acceded to by the Secretary of the Navy, and the outlays for the transportation authorized. The description of the two journeys across the continent, with the accompanying tables of physical constants for a large number of stations, and meteorological records during each transit, form a valuable contribution to the results of the expedition. And together with these are published reports by the most competent authorities whose aid Gilliss could enlist on his return, giving descriptions and classifications of the various objects of natural history collected during the three years. There is also an interesting chapter by Mr. Ewbank, upon the curious antiquities brought home from Chile and Peru.

The third volume contains the observations for deducing the parallax, together with their discussion as heretofore described. The fourth and fifth, as yet unpublished, are, as I have stated, to contain respectively the absolute determinations with the meridian-circle, and the invaluable circumpolar zones.

If I have devoted much time and space to the description of this interesting and valuable expedition, it is because few others on record have accomplished so much, in proportion to the means provided, and because the results have been especially honorable to all those who took part in it—from the legislators, who introduced the measure in Congress, to the Chilian government, who purchased the instruments and equipments, when the contemplated work was done, and have established the first really National Observatory of the Western Continent. And moreover, in so far as the admirable Naval Observatory in this city may be regarded as a National Observatory, Gilliss's name is no less inseparably connected with the one than with the other.

Professor Moesta, a graduate of Marburg in Hesse, and a Chilian by residence, was appointed Director of the National Observatory of Chile, and has conducted it with honor to himself, and to the government which placed it in his charge.

On the 1st October, 1852, Gilliss left Santiago on his return homeward, and in the following month arrived in the United States, after an absence of three years and a quarter.

During the four years next ensuing, he was engaged under orders from the Navy Department in reducing the observations, and the preparation of his narrative, and of the work on Chile. In September, 1855, however, a great blow fell upon him. The Naval Retiring Board, under orders to report to the Secretary of the Navy the names of all officers who were in their judgment incapable of performing all their duties both ashore and afloat, in order that they be placed upon the "reserved list" with furlough pay, reported the names of 201 out of the 712 officers in the several grades prescribed by law. Of these 201 names, 49 were stricken from the rolls, and the remainder placed upon the reserved list. Strange as it may seem, Gilliss's name was among the number, the reason assigned—indeed the only one assignable—being, that twenty years had elapsed since his last sea service.

Gilliss felt this imputation keenly. His first volume only had appeared, and the Secretary promptly notified him that he would be retained on the same duty of preparing the remaining five for publication, and without diminution of his salary. Still a stigma was affixed, as he thought, and he fancied that disgrace, or at least humiliation, attached to his new position. He had fulfilled the first duty of an officer for all these years by implicitly obeying orders. No one of these orders had ever been solicited by him, excepting that for the charge of the expedition to Chile. Some of them had indeed been adverse to his known wishes, and in a published letter sent to those learned societies which had enrolled him among their members, he earnestly, yet with remarkable gentleness and courtesy of language, set forth the injustice with which he considered that he had been treated. He urged that a man of trained mind could no more forget the profession acquired in the vigor of his youth, than he could forget the art of swimming, mastered at the same period of life, and that the only ground on which his "retirement" could be advocated or defended, namely, a presumed inability by reason of disuse to perform the duties of an officer at sea, was utterly fallacious. Yet, waiving that point, how could an officer be justly set aside for alleged incompetency in his profession, when his life had been spent in active, energetic fulfilment of orders of his superiors, over which he had no control—even had these orders not been given without solicitation on his own part.

I pass this subject by, for it can do no good to dwell upon it. It is not for me, nor indeed for any of us, to pass judgment upon acts purely professional and technical; and there can be no one more painfully aware how frequently great individual injustice seems inseparable from the execution of plans judicious in themselves, and conducive to the public welfare. It is not an infrequent observation that wise laws do not always seem to go hand in hand with equity.

It may be well to state here that when, after the flight of Maury, in 1861, Gilliss had been assigned to the post which the scientific world had expected for him sixteen years before, he soon received a commission as Commander, and a little more than a year later he received a commission as Captain, in the regular order of his seniority.

Early in the summer of 1858, while he was still engaged in the reduction of his observations, Gilliss, seeing the announcement that European observers were preparing to visit Brazil for the purpose of observing the total eclipse of the sun in September following, and perceiving that no arrangements were in progress for sending observers to the rainless region on the western coast of South America, volunteered his services. On the 8th of June he addressed a letter to Professor Henry, as Secretary of the Smithsonian Institution, offering to undertake the journey; and, the proposition meeting a ready response, arrangements were speedily made and carried into execution. The Coast Survey furnished instruments for determining geographical position and time, as also a tent; the Naval Observatory contributed two pocket-chronometers, and Mr. Fitz hurried to its completion, and lent for the enterprise, a 4½-inch equatorial, mounted on a stand adjustable for different latitudes. Accompanied by a young friend from New York, Gilliss left that city on the 5th of August, for Payta, in Peru, where they arrived on the 21st of the same month.

It is intensely gratifying to the lover of science, in reviewing the history of this expedition, to note the international courtesies, the liberality, and the appreciation of scientific research, which it elicited on every side. Doubtless the personal reputation of Gilliss, especially high in that direction where so much of his scientific efforts had been expended, contributed largely to these amenities; and to his dignified yet modest bearing, together with his unfailing courtesy, unquestionably much was due. Still, such aid and ready assistance as the expedition received on every side clearly manifested an earnest desire to aid the scientific enterprise in every possible way. The United States Mail Steamship Company, the Panama Railroad Company, and the Pacific Mail Steamship Company, gave the use of their ships and cars, offering, moreover, every other assistance in their power. The British Steam-Navigation Company granted free transport with great cordiality, and instructed their agents to aid the objects of the expedition in every possible way. "And so faithfully were these instructions carried out," says Gilliss, "that I cannot too earnestly express my appreciation of the considerate kindness shown me by the manager and agents of the line at Callao, Valparaiso, and Panama, or of the captains while making the voyages on board their ships." "During two weeks' detention on the isthmus," when returning, "we were guests of the Pacific Mail Steamship Company." On the day of his arrival at Payta, was received, through the captain of a war steamer lying in that port, a message from the Admiral commanding the French fleet in the Pacific, offering to carry him to any point on the coast, or to facilitate the observations by any means at his disposal. The Peruvian Minister at Washington had given official letters commending the expedition to the interest of the local authorities. The cases containing instruments and personal effects were passed unopened through the custom-house; the captain of the port, the prefect of the province, the governors of the towns, and the inhabitants of the regions traversed, afforded all the official aid and all the personal hospitality in their power.

Finding that the atmosphere near the coast was very unfavorable about the hour of sunrise, at which time the eclipse would occur, it was decided to travel inland to some point near the Andes, and close upon the central line of totality. Leaving the zenith-telescope of the Coast Survey, and a chronometer, with the captain of the French steamer, who proceeded with the steamer to a point about sixty miles south of Payta, where the central line of the shadow would first touch the continent, Gilliss himself, with Mr. Raymond, his companion, carrying the smaller instruments, and after despatching the Fitz telescope, the tent and provisions, half a day in advance of them, took their way inland on muleback. "The country between the two places is a desert of sand, which is so drifted by the strong daily winds, that the mule paths are obliterated almost as soon as made, and the traveller finds his way by the tall stakes that have been planted, and the skeletons of animals that have died on the road from heat and thirst." Passing through the town of Piura, where they rested for a day and obtained important local information, they followed the dry beds of the so-called rivers, pitching their tent nightly. Water for the party, none of the best, was carried by the muleteers in calabashes. On the second day the guide lost his way, and it was not until noon of the fourth day from Piura, the fifth of their travel, that they reached the little town of Olmos, in just 6° south latitude, which had been chosen for the place of observation. But the journey had been too exhausting, and long before his arrival Gilliss was suffering from an intense fever. Here his energy and determination made themselves strikingly manifest. The fever assuming an intermittent type, he availed himself of its intervals to select a site for his tent, about one mile from the town, to obtain time for his chronometers and observations for latitude, and, while lying prostrate on the ground, he instructed his companion as to each part of the telescope, until it was properly mounted, for on the next morning the eclipse was to take place. Happily the fever had abated when morning came, and the eclipse was satisfactorily observed, with all the magnificent phenomena of a total obscuration, which lasted for more than a minute. Descending to the town early next day, they reached Payta on the sixth day thereafter. The results of the observations of Messrs. Gilliss, Raymond, and the French officers, are published in the Smithsonian Contributions to Knowledge.

The tedious, exhausting, and even hazardous journey across the Peruvian desert had been undertaken in spite of the fact that a point on the sea-coast called Lambayeque was but twenty-two Peruvian leagues from Olmos, the road passing along a valley which offers resources throughout the whole distance. But Gilliss had been informed by the commander of the steamer that the surf at Lambayeque was heavy, and that the risk of landing there with instruments might produce detention. He was not the man to hesitate under such circumstances, and chose the desert, with its privations and hardships, but its increased chances of success. The event confirmed the propriety of the choice; for when Dr. Moesta, who came up from Chile for the same purpose, endeavored to land at Lambayeque, the surf precluded all possibility of landing until the fifth. In spite of his best efforts, he could only reach a village five leagues south of Olmos before the 7th, the morning of the eclipse, and the morning was cloudy there. In December, Gilliss again reached New York, having availed himself of an opportunity of accompanying Dr. Moesta on his return to Chile, and thus revisiting for a few days the friends whom he had left in Santiago six years before.

Meanwhile, as the various reductions and publications of the Parallax Expedition went on, Gilliss was not idle in other directions. As the time for the total eclipse of 1860 approached, he suggested the noted expedition for its observation which was despatched to Labrador under our colleagues, Messrs. Alexander and Barnard, by Mr. Bache for the Coast Survey, and that sent by Mr. Winlock of the Nautical Almanac to the Hudson's Bay territory, under Professors Ferrel and Newcomb. He himself took charge of a third, to Washington Territory, also under the auspices of the Coast Survey. He observed the eclipse with great success, assisted by his eldest son, now a captain in the army, but then in the Coast Survey service, and Mr. A. T. Mosman, also of the Coast Survey. The point originally selected had been upon the Cascade Mountains near Puget's Sound, since this eclipse also would occur nearly at sunrise, and it was feared that the mountain ranges might intercept the view. But on arriving at Fort Steilacoom the officers of the garrison relieved his apprehensions on this score by showing the inaccuracy of the topographical information previously obtained. A point was found only ten miles from the fort, upon a small open prairie, which commanded an excellent view of the sun at its rising, and, profiting by the experience gained at Olmos, and the greater force at his disposal, the observations made here were even more successful. A very singular phenomenon was here observed, which is most graphically described in Gilliss's report. All the prismatic colors flashed with wondrous brilliancy in circular bands and rapid revolution over the black disk of the moon, changing their relative places like the figures of a kaleidoscope. The suspicion naturally arises that this phenomenon was physiological, but the contemporaneous view of the same spectacle by an observer at Fort Steilacoom, ten miles distant, using an opera-glass, seems to throw some doubt upon this explanation.

On the memorable 15th of April, 1861, Commander Maury fled from his post at the Naval Observatory, leaving in his haste unquestionable proofs of treasonable correspondence with the public enemy. A day or two later, orders were issued to Gilliss to assume the charge of the institution, and poetic justice, though long deferred, was at last fulfilled. The sudden transformation which took place was like the touch of an enchanter's wand. Order sprang from chaos, system from confusion, and the hearts of the faithful few who had struggled on for years, hoping against hope, were filled with sudden joy. Short time elapsed before their number was augmented by the advent of new astronomers, and in the first week of January following, the reduced observations of the year were ready for the printer—an unwonted sight, for the last volume printed contained the observations of 1849 and 1850, while only one-seventh part of the southern zones, planned by Coffin and Hubbard, and observed between the years 1846 and 1849, had been reduced, and but one-thirteenth part published.

You need no reminder, gentlemen, of the suddenness with which the American Navy sprang into existence, almost like Minerva in full panoply from the brain of Jove at the stroke of Vulcan. Apart from scientific duty, it fell to Gilliss's share to provide for the equipment of all national vessels with charts and instruments; and this he did, until the passage of the next supply-bill, from the unexpended balance of Maury's annual appropriation made in times of peace. But this was the least of his deserts: he did it from home resources; he gave a new impulse to the industry and skill of mechanic artists and opticians in the United States, and for the first time laid down and carried out the principle that no instrument should be imported for the American navy which could be manufactured as well at home. The workshops of the scientific artisans of whom we are so justly proud sprang into new activity, and the devices and admirable workmanship then and thus evoked reflect upon Gilliss's memory an honor second only to that due to the men whose ingenuity and enterprise responded to his summons—men who need no mention here, for we delight to honor them. Spy-glasses, sextants, compasses, chronometers, barometers, and all the many minor instrumental equipments of the navy, were so ordered that the navy, the artisans, and the public purse were alike gainers. The American Nautical Almanac, which had so long earned scientific reputation for us abroad, was brought into use on board our own national vessels, and for the first time officers held glasses of American make, to note the running of American log-lines.

The energies of the Observatory were not merely stimulated, but became directed by a definite policy in the prosecution of distinct aims. The reduction of the accumulated mass of the whole ten, and the greater part of fourteen years' crude observations, was provided for, and plans for their publication were matured. The various astronomical institutions of the land were invited to systematic co-operation for the prosecution of organized schemes of joint activity. The long-deferred hope of determining the parallax by simultaneous observations in Chile and in the United States was revived, and by a strange coincidence of circumstances, the last morning of his life witnessed the publication of the result deduced, according to the original plan, by the joint activity of the two observatories founded through his own exertions five thousand miles apart. The results deduced by Messrs. Ferguson and Hall from meridian and from micrometric observations closely accord with each other, and with those deduced within the last few years by other methods—and a further discussion of materials from two other observatories shows a close corroboration of these values by one of them.

While the first public announcement of these interesting deductions was issuing from the press, Gilliss breathed his last. The message for his departure could not have come more suddenly, yet it found him prepared, and with his lamp trimmed and burning. A month before, we had parted from him here in the full culmination of his meridian power, and most of us had felt the cordial pressure of his friendly grasp. It was but a day before that he had welcomed home his eldest son, freed from the horrors of a rebel dungeon. It was but a few minutes since he had welcomed the new day. We hoped from him yet much more for the welfare and the honor of our country. Yet we will not call his death untimely. He had lived to see the would-be destroyers of the republic melting away, like the night dew as the sun grows high—to behold his country, amid struggles which his enemies had fondly deemed her death-throes, putting forth new tokens of life, and inaugurating a new era for her science as well as for her liberties. After years of discouragement and disappointment, he had seen his own services recognized. While the institution in the other hemisphere whose successful foundation was due to his own ability and endeavor had become permanent and active, he had enjoyed the yet greater satisfaction of seeing the cloud disperse which had so long overshadowed that other institution which had been one of the dearest objects of his life, and whose reputation his earliest and his latest labors have alike identified with his own. When charlatanism and disloyalty were no longer predominant there, we may imagine the just pride with which he had entered its doors and assumed command. When he departed, the new day-star which has risen upon our nation was high enough in heaven to show him the auguries of the morning, yet it had not sufficed to throw those dark shadows which we must yet encounter, or to display the unwelcome forms which yet remain for our eyes. No lingering disease wasted his manly powers, nor was his active mind fettered in the dungeon of an exhausted body. His brain was full of large ideas, his heart teeming with kindly affections, when "God's finger touched him, and he slept."

MEMOIR

OF

ALEXANDER DALLAS BACHE.

1806–1867.

BY

JOSEPH HENRY.

READ BEFORE THE NATIONAL ACADEMY, APRIL 16, 1869.

BIOGRAPHICAL MEMOIR

OF

ALEXANDER DALLAS BACHE.

GENTLEMEN OF THE ACADEMY:—

ALEXANDER DALLAS BACHE, whose life and character form the subject of the following memoir, was the son of Richard Bache, one of eight children of Sarah, the only daughter of Dr. Benjamin Franklin. His mother was Sophia Burret Dallas, daughter of Alexander J. Dallas, and sister of George M. Dallas, whose names are well known in the history of this country, the former as Secretary of the Treasury, and the latter as Vice-President of the United States, and subsequently as minister to the Court of St. James.

The subject of our sketch was born in Philadelphia, on the 19th of July, 1806. At an early age he became a pupil of a classical school, and was distinguished by an unusual aptitude in the acquisition of learning. Shortly before arriving at the age of fifteen he was appointed a cadet at the National Military Academy at West Point. Here, though the youngest pupil, he soon attained a high grade of scholarship, which he maintained during the whole of his course, and was finally graduated in 1825, at the head of his class. His merit was in this case the more conspicuous, inasmuch as the class is shown to have been one of unusual ability, by having numbered no less than four successful candidates for the honor of adoption into the Corps of Engineers. It has been mentioned as a solitary instance in the history of the Academy, noted for its rigid discipline, that young Bache passed through the entire course of four years without having received a mark of actual demerit, and, what is perhaps not less uncommon, without having called forth the least manifestation of envy on the part of his fellow-pupils. On the contrary, his superiority in scholarship was freely acknowledged by every member of his class, while his unassuming manner, friendly demeanor, and fidelity to duty secured him the affection as well as the respect of not only his fellow-pupils, but also of the officers of the institution. It is also remembered that his classmates, with instinctive deference to his scrupulous sense of propriety, forbore to solicit his participation in any amusement which in the slightest degree conflicted with the rules of the Academy. So far from this, they commended his course, and took pride to themselves, as members of his class, in his reputation for high standing and exemplary conduct. His room-mate, older by several years than he was, and by no means noted for regularity or studious habits, constituted himself, as it were, his guardian, and sedulously excluded all visitors or other interruptions to study during the prescribed hours. For this self-imposed service, gravely rendered as essential to the honor of the class, he was accustomed jocularly to claim immunity for his own delinquencies or shortcomings. But whatever protection others might require on account of youth and inexperience, young Bache needed no guardian to keep him in the line of duty. Impressed beyond his years with a sense of the responsibility which would devolve upon him as the eldest of his mother's family, entertaining a grave appreciation of the obligations involved in his education at the National Academy, he resolved from the first to exert his energies to the utmost in qualifying himself for the duties which he might be called upon to discharge, whether in professional or private life. Nor was he uninfluenced in this determination by a consciousness that as a descendant of Franklin he was, in a certain degree, an object of popular interest, and that on this account something more than an ordinary responsibility rested upon him. On a mind constituted like his an influence of this kind could not but exert a happy effect.

The character which he established for gentleness of manner and evenness of temper was not entirely the result of native amiability, for when a child he is said to have been quick-tempered, and at later periods of his life, when suddenly provoked beyond his habitual power of endurance, he sometimes gave way to manifestations of temper which might have surprised those who only knew him in his usual state of calm deportment. These ebullitions were, however, of rare occurrence, and always of short duration. His marked characteristic was the control which he had acquired over his passions and feelings, and it was this which enabled him to suppress all tendency to self-indulgence, to pursue with unremitting perseverance the course he had marked out, to observe an undeviating regard for truth and justice, and to cherish habitually all that would tend to exemplify the kindlier affections of the heart.

Although young Bache was perhaps predisposed, from hereditary influence, to form correct habits and adopt high moral principles, yet these dispositions might have remained dormant had it not been for the early training and the watchful care of his noble mother. From his earliest days she checked with gentle reproof every indication of childish revolt against wholesome restraint, and steadily carried out her system of discipline so gently and yet so effectually that it met with scarcely any opposition, and left the conviction that she was always in the right. Her maternal solicitude did not end with his being placed under military rule, but was continued through his whole course by means of a ready pen. In the language of one who was permitted to read her letters to her son while at West Point, "nothing could be more admirable than the way in which, amid pleasant gossip and family news, she would inspire her son with high sentiments and encourage him to persevering industry."

As an illustration of his persistency of purpose, it is related that, when a recitation of more than common length or difficulty was to be prepared for the morrow, it was no unusual practice of his to place himself on a seat of unstable equilibrium, which by giving way when volition was about to lose its power recalled his flagging attention to the allotted task.

After graduating he was selected, on account of his scholarship, to remain at the Academy as an assistant professor. In this position, which gave him an opportunity to review his studies and extend his reading, he continued one year; when, at his own request, he was assigned to engineering duty under the late General, then Colonel, Totten, at Newport, Rhode Island. Here he remained two years, engaged in constructing fortifications, devoting his extra hours to the study of physics and chemistry, and, as a recreation, collecting and labelling the shells of that region. But the most important event of this period of his life, and that which, doubtless, contributed in a large degree to his future success, was his becoming acquainted with and subsequent betrothal to Miss Nancy Clarke Fowler, the daughter of an old and highly-respected citizen of Newport. With the stinted pay of a lieutenant of engineers, out of which his mother and her younger offspring were to be provided for, marriage was not to be thought of, excepting as an event in the remote distance. Fortunately as unexpectedly, however, a change now took place in his circumstances which enabled him to gratify the earnest wish of his heart and to secure to himself a companion and helpmate who lavished upon him all her affections, and through his life ardently devoted all her thoughts and energies to sustain, assist, and encourage him. The change alluded to, and which opened to him an uninterrupted career of usefulness during the whole of his active life, was the result of an invitation to the chair of natural philosophy and chemistry in the University of Pennsylvania, at Philadelphia. He accepted the position with that unaffected diffidence which is the usual concomitant of true but untried merit, though, as might have been anticipated, his eventual success was commensurate with the industry and ability which had marked his previous progress. Having already had some experience as a teacher, he the more readily gained the entire confidence of the authorities of the University and the affection of his pupils. He did not, however, rest satisfied with the occupation of teacher, or with merely imparting knowledge obtained by the labors of others, but sought to enlarge the bounds of science by discoveries of his own. As auxiliary to this, he became a member of the Franklin Institute, a society then newly established for the promotion of the mechanical arts. This society, which still maintains a vigorous existence, was well calculated to exhibit his talents and develop his character. It brought him into intimate association with the principal manufacturers, engineers, and artisans of the city, and into relations of friendship with a large number of young men destined, in more advanced life, to exert an extended influence on public affairs. He was appointed chairman of one of the most important of its committees, and was chosen as the expounder of the principles of the institute at its public exhibitions. Facilities were thus afforded him for the prosecution of science, which he could not have well commanded in any other position. Workshops were thrown open to him, and skilful hands yielded him ready assistance in realizing the conceptions of his suggestive mind. His descent from the illustrious statesman and philosopher whose name the institute bears, and who is almost regarded as the tutelar saint of Philadelphia, no doubt contributed to a prepossession in his favor, but the influence which he acquired and maintained was due to his own learning, industry, ability, and courtesy. To these he owed the favor and distinction of having conferred upon him the principal directorship of the scientific investigations of the institute, and the opportunity which it afforded him of so greatly contributing to the usefulness of the society and to the advancement of his own reputation.

For a full account of the labors in which he was engaged in his connection with the Franklin Institute we must here be content with referring to the volumes of its journal from 1828 to 1835 inclusive. We may pause a moment, however, to notice the investigations relating to the bursting of steam-boilers, of which he was the principal director. The public mind had, at that epoch, been so frequently and painfully called to this subject that the institute was induced to organize a series of systematic researches in regard to it, the importance of which was soon recognized by the General Government in the form of an appropriation for defraying the attendant expenses. In the prosecution of these inquiries a large amount of information relative to explosions, and suggestions as to their causes, was first collected by correspondence, and on this was based a series of well-devised experiments, which were executed with signal address, and the results interpreted with logical discrimination. The conclusions arrived at were embodied in a series of propositions, which, after a lapse of more than thirty years, have not been superseded by any others of more practical value. The most frequent cause of explosion was found to be the gradual heating of the boiler beyond its power of resistance; and next to this, the sudden generation of steam by allowing the water to become too low, and its subsequent contact with the overheated metal of the sides and other portions of the boiler. The generation of gas from the decomposition of water as a cause of explosion was disproved, as was also the dispersion of water in the form of spray through superheated steam. These experiments were not unattended with danger, and required, in their execution, no small amount of personal courage. Accidents were imminent at almost every stage of the investigation; and in some instances explosions were produced which alarmed the neighborhood. So true is it that in the pursuit of science dangers are oftentimes voluntarily encountered, exacting no less courage or firmness of nerve than that which animates the warrior in the more conspicuous but scarcely more important conflicts of the battle-field.

The attention of Mr. Bache at this period was not exclusively devoted to his labors in connection with the Franklin Institute. He was also a member of the American Philosophical Society, and, as such, in association with Hare, Espy, and others interested in the pursuit of various branches of physics and chemistry. He erected an observatory in the yard of his dwelling, in which, with the aid of his wife and of his former pupil, John F. Fraser, he determined with accuracy, for the first time in this country, the periods of the daily variations of the magnetic needle, and by another series of observations the connection of the fitful variations of the direction of the magnetic force with the appearance of the aurora borealis.

Again, in connection with his friend, Mr. Espy, he made a minute survey of a portion of the track of a tornado, which visited New Brunswick, in New Jersey, on the 19th of June, 1835, and from the change of place and relative position of the trees and other objects, as left by the wind, he succeeded in establishing the fact, in accordance with the hypotheses of Mr. Espy, that the effects of the storm were due to an ascending and progressive column of air, by which all objects within the influence of the disturbance, on either side the track, were drawn inward, and not due, as had been supposed, to a horizontal rotation at the surface, which would tend to throw them outward by centrifugal projection. In co-operation with Professor Courtenay, he also made a series of determinations of the magnetic dip at various places in the United States. Indeed, terrestrial magnetism was with him a favorite subject, to which he continued to make valuable contributions at intervals during his whole life. The phenomena of heat likewise engaged much of his attention, and he was the first to show, contrary to generally-received opinion, that the radiation and consequent absorption of dark heat is not affected by color. His investigations in this line were suddenly brought to a close by an accident, which we may be allowed to mention as furnishing an illustration of his self-control and considerate regard for the feelings of others. After an expenditure of money which he could ill afford, and of time withdrawn from the hours due to repose, he had procured and arranged on a stand a series of delicate instruments intended for a long-meditated experiment on radiant heat. During his temporary absence his mother, in hurriedly passing through the apartment, accidentally caught in her dress the support of the apparatus and brought the whole to the floor, a mass of mingled fragments. The author of this disaster was so painfully affected by the destruction, of which she had been the unintentional cause, as to be obliged to leave to his wife the task of breaking the unwelcome tidings to her son. On receiving the information, he stood for a moment, perfectly silent, then hurried out into the open air to conceal his emotion and tranquillize his feelings. After a short interval he returned, calm, affectionate, and apparently cheerful, and neither by word nor look gave any indication of the pain and disappointment he had so severely experienced.

It should not be forgotten that the labors to which we have alluded were performed in hours not devoted to his regular duties as a professor in the University. To these he was obliged to give three hours a day, besides other time to the preparation of illustrations for his lectures, while several evenings of the week were claimed by committees of the Franklin Institute and the Philosophical Society. He was enabled to execute these multifarious labors by a division of his time into separate periods, to each of which was allotted its special occupation. By a rigid adherence to this system he was always prompt in his engagements, was never hurried, and found time, moreover, to attend to the claims of friendship and society. He was a zealous and successful teacher, to whom the imparting of knowledge was a source of unalloyed and inexhaustible pleasure. His pupils could not fail to be favorably impressed by his enthusiasm and influenced by his kindness. He always manifested an interest not only in their proficiency in study, but also in their general welfare. They regarded him with affection as well as respect, and while in other class-rooms of the University disorder and insubordination occasionally annoyed the teachers, nothing was to be witnessed in his, but earnest attention and gentlemanly deportment.

His success as an instructor affords a striking confutation of the fallacy which has not unfrequently been advocated in certain quarters, that men devoted to original research and imbued with habits of mind which it generates are not well qualified for the office of instructors. So far is the proposition from having any foundation in fact, that it is precisely among the most celebrated explorers of science of the present century that the most successful and noted teachers have been found. In proof of this the illustrious names of Priestley, De Candolle, Dalton, Davy, Oersted, Faraday, and a host of others, immediately occur. At the same time it cannot be denied that it is questionable economy to devote to the drudgery of drilling youth in the elements of knowledge, a mind well qualified by nature and training to enlarge the boundaries of thought and increase the stores of knowledge. But it is equally clear that the practice of teaching is, to a certain extent, not incompatible with the leisure and concentration of mind requisite for original research; that the latter must, in fact, act beneficially alike on the instructor and instructed; the former gaining in clearness of conception in the appreciation of the new truths he is unfolding by imparting a knowledge of their character to others, while the latter catch, by sympathy, a portion of the enthusiasm of the master, and are stimulated to exertions of which they would otherwise be incapable.

In 1836, when Professor Bache had just attained the thirtieth year of his age, his attention and energies received a new direction, constituting, as it were, a new epoch in his life. This change was caused by a movement on the part of the trustees of the Girard College for Orphans, an institution munificently endowed by a benevolent citizen of Philadelphia. Preparatory to organizing this institution it was thought desirable to select a suitable person as president, and to send him abroad to study the systems of education and methods of instruction and discipline adopted in Europe. The eyes of the entire community were with one accord directed to our professor as the proper man for this office. He had, however, become enamored with the pursuit of science, and it was with difficulty that he could bring himself to regard with favor a proposition which might tend to separate him from this favorite object. The consideration of a more extended field of usefulness at length prevailed, and he accepted, though not without some lingering regret, the proffered position. No American ever visited Europe under more favorable circumstances for becoming intimately acquainted with its scientific and literary institutions. His published researches had given him a European reputation, and afforded him that ready access to the intelligent and influential classes of society which is denied the traveller whose only recommendation is the possession of wealth. It cannot be doubted that he was also favored in this respect by the admiration which in Europe still attaches to the name of his renowned ancestor.[1] He was everywhere received with marked attention, and from his moral and intellectual qualities did not fail to sustain the prepossessions in his favor and to secure the friendship and esteem of the most distinguished savants of the Old World.

He remained in Europe two years, and on his return embodied the results of his researches on education in his report to the trustees of Girard College. This report forms a large octavo volume, and is an almost exhaustive exposition of the scholastic systems and methods of instruction in use at the time in England, France, Prussia, Austria, Switzerland, and Italy. It has done more, perhaps, to improve the theory and art of education in this country than any other work ever published; and it has effected this not alone by the statement of facts derived from observation, but also by the inferences and suggestions with which it abounds. The accounts which are given of the different schools of Europe are founded on personal inspection; the results being noted down at the time with the writer's habitual regard to accuracy.

After completing his report he was prepared to commence the organization of the Girard College, but the trustees, partly on account of the unfinished condition of the building, and partly from a delay in the adjustment of the funds of the endowment, were not disposed to put the institution into immediate operation. In the mean time Professor Bache, desirous of rendering the information he had acquired of immediate practical use, offered his services gratuitously to the municipal authorities of Philadelphia, to organize, on an improved basis, a system of public education

[1] The force of this sentiment was quaintly but strongly marked by a slight incident which occurred when he was in Germany. An elderly savant, on being introduced, clasped him in his arms, saluted him with a kiss on either cheek, and greeted him with the exclamation, "Mein Gott, now let me die, since I have lived to see with mine own eyes an emanation of the great Franklin!" This compliment was perhaps more flattering than agreeable, since the old professor in question was wont, after the fashion of his day, to stimulate his lagging faculties by frequent and profuse extractions from the snuff-box.

for that city. This offer was gladly accepted, and he commenced the work with his usual energy and with the cordial support of the directors and teachers of the common schools. At the end of the year, finding that the trustees of the college were still unprepared to open the institution, he relinquished the salary, but retained the office of president, and devoted his time mainly to the organization of the schools. He was now, however, induced to accept from the city, as the sole and necessary means of his support, a salary much less than the one he had relinquished. The result of his labors in regard to the schools was the establishment of the best system of combined free education which had, at that time, been adopted in this country. It has since generally been regarded as a model, and has been introduced as such in different cities of the Union.

In 1842, having completed the organization of the schools, and Girard College still remaining in a stationary condition, he resigned all connection with it, and, yielding to the solicitations of the trustees of the University, returned to his former chair of natural philosophy and chemistry, in order that he might resume the cultivation of science. Not that it is to be inferred that in his devotion to the advancement of education he had relinquished or deferred the scientific pursuits to which the habit of his mind and the bent of his genius continually impelled him, for during his travels in Europe he had been careful to provide himself with a set of portable instruments of physical research, and, as a relief from the labors imposed by the special object of his mission, he instituted a connected series of observations at prominent points on the Continent and in Great Britain, relative to the dip and intensity of terrestrial magnetism. These observations were made with the view of ascertaining the relative direction and strength of the magnetic force in Europe and America, by the comparison of parallel series of observations in the two countries with the same instruments. They also served, in most instances, to settle with greater precision than had previously been attained the relative magnetic condition of the points at which they were made.

Though the organization of the schools of such a city as Philadelphia might seem sufficient to absorb all his energy and self-devotion, yet even in the midst of this labor we find our late colleague actively co-operating in the great enterprise of the British

Association to determine by contemporaneous observations, at widely separated points, the fluctuations of the magnetic and meteorological elements of the globe. This co-operation, in which no doubt a feeling of national pride mingled itself with his ardor for the advancement of science, consisted primarily in the establishment of an observatory, to which the trustees of Girard College contributed a full series of instruments, combining all the latest improvements, and which was supported by the American Philosophical Society, and a number of liberal and intelligent individuals. The observations which were here continued at short intervals, both by day and night, for five years, form a rich mine of statistics, from which, until within the last few years of his life, the professor drew a highly interesting series of results, without exhausting the material. In addition to these observations, he made during his summer vacations a magnetic survey of Pennsylvania.

He was not destined to remain long in his old position in the University. Before he had become fairly settled in it and had renewed his familiarity with its duties, he was called in November, 1843, on the occasion of the death of Mr. Hassler, Superintendent of the United States Coast Survey, to fill the important sphere of public duty thus rendered vacant. His appointment to this position was first suggested by the members of the American Philosophical Society, and the nomination fully concurred in by the principal scientific and literary institutions of the country. In this movement he himself took no part, and indeed regarded the position as one not to be coveted; for while it opened a wide field for the exercise of talent and the acquisition of an enviable reputation, it involved responsibilities and presented difficulties of the gravest character. Professor Bache was not one of those who, abounding in self-confidence, imagined themselves equal to every exigency, or who seek the distinctions and emoluments of office without any regard to the services to be rendered or the duties discharged. On the contrary, though early and continued success must have tended to increase his self-esteem, each new position to which he was called was entered upon with feelings of solicitude rather than of exultation. He rightly judged that the proper moment for self-congratulation is not at the beginning of an arduous and precarious enterprise, but at the time of its full and successful accomplishment. Nor can it be necessary to add that this characteristic contributed largely to his success. In civil service as in the camp, the leader to whom all look with confidence is not he who, with blind and arrogant self-reliance, disdains caution as unworthy of courage, but he who, sensitively alive to the dangers to be encountered, exerts every faculty in calling to his aid every resource which may tend to secure victory or facilitate retreat.

With whatever misgivings Professor Bache may have undertaken the task to which he was assigned, it may be truly said that no living man was so well qualified as himself to secure the results which the nation and its commercial interests demanded. His education and training at West Point, his skill in original investigations, his thorough familiarity with the principles of applied science, his knowledge of the world, and his gentlemanly deportment, were all in a greater or less degree essential elements in the successful prosecution of the survey. It would appear as if the training and acquisition of every period of his life, and the development of every trait of his character, had been specially ordained to fit him in every respect to overcome the difficulties of this position. Besides the qualifications we have enumerated, he possessed rare executive ability, which enabled him to govern and guide the diverse elements of the vast undertaking with consummate tact and skill. Quick to perceive and acknowledge merit in others, he rapidly gathered around him a corps of men eminently well qualified for the execution of the tasks to which he severally assigned them.

The Coast Survey had been recommended to Congress by President Jefferson as early as 1807, but it was not until ten years afterward that the work was actually commenced, under the Superintendence of Professor Hassler, an eminent Swiss engineer, whose plans had been previously sanctioned by the American Philosophical Society. Though the fundamental features of the survey had been established on the most approved scientific principles, yet so frequent were the changes in the policy of the government, and so limited were the appropriations, that even up to the time of Professor Bache's appointment, in 1843, little more than a beginning had been made. The survey, so far as accomplished, extended only from New York Harbor to Point Judith, on the east coast, and southward to Cape Henlopen. The new Superintendent saw the necessity of greatly enlarging the plan, so as to embrace a much broader field of simultaneous labor than it had previously included. He divided the whole coast line into sections, and organized, under separate parties, the essential operations of the survey simultaneously in each. He commenced the exploration of the Gulf Stream, and at the same time projected a series of observations on the tides, on the magnetism of the earth, and the direction of the winds at different seasons of the year. He also instituted a succession of researches in regard to the bottom of the ocean within soundings, and the forms of animal life which are found there, thus offering new and unexpected indications to the navigator. He pressed into service, for the determination of the longitude, the electric telegraph; for the ready reproduction of charts, photography; and for multiplying copper-plate engravings, the new art of electrotyping. In planning and directing the execution of these varied improvements, which exacted so much comprehensiveness in design and minuteness in detail, Professor Bache was entirely successful. He was equally fortunate, principally through the moral influence of his character, in impressing upon the government, and especially upon Congress, a more just estimate of what such a survey required for its maintenance and creditable prosecution. Not only was a largely-increased appropriation needed to carry out this more comprehensive plan, but also to meet the expenses consequent upon the extension of the shore-line itself. Our sea-coast, when the survey commenced, already exceeded in length that of any other civilized nation, but, in 1845, it was still more extended by the annexation of Texas, and again, in 1848, by our acquisitions on the Pacific. Professor Bache was in the habit of answering the question often propounded to him by members of Congress, "When will this survey be completed?" by asking, "When will you cease annexing territory?" a reply not less significant at the present day than when it was first given, and which may continue long to be applicable under the expansive tendencies of our national policy.

When Professor Bache took charge of the survey, it was still almost in its incipient stage, subjected to misapprehension, assailed by unjust prejudice, and liable, during any session of Congress, to be suspended or abolished. When he died, it had conquered prejudice, silenced opposition, and become established on a firm foundation as one of the permanent bureaus of the executive Government. The importance of the work, which was always highly appreciated by the mariner, became strikingly obvious to the general public through the service which it rendered during the late war, in furnishing accurate charts and sailing directions for the guidance of our squadrons along the southern coast. Nor was this alone; an active participation was also borne by the officers of the survey in the attack of the United States Navy on Sumter, Port Royal, Fort Fisher, Mobile, New Orleans, and other strongholds, while constant aid was rendered by them in the navigation of the inlets and channels, and in the avoidance of hidden rocks or shoals with which none could be more minutely acquainted. Though the value of the survey was signally conspicuous on these occasions, it needs but little reflection to be convinced of its essential connection with the general prosperity of the country. Whatever diminishes the danger of departure from or an approach to our shores facilitates commerce, and thus renders more valuable the products of our industry, even in portions of our land most remote from the sea-board. But the survey should not be viewed alone in its economical relations, since, as an enlightened and liberal people, we owe it to the great community of nations and the cause of humanity to supply the world with accurate charts of our precarious coast, as well as to furnish it with all the other aids to safer navigation which the science and experience of the age may devise.

Professor Bache, with his enlightened appreciation of the value of abstract science, kept constantly in view the various problems relative to the physics of the globe, which are directly or even incidentally connected with the survey of the coast, and ever cherished the hope of being permitted to complete his labors by their solution. Among these was a new determination of the magnitude and form of the earth, and the variations in the intensity of terrestrial gravity at various points on the continent of North America; the discussion of the general theory of the tides; the magnetic condition of the continent; and the improvement of the general map of the United States, by determining its relation to the coast line, and the precise geographical positions of the most important points in the interior. Though his hopes in regard to these problems were not destined to be realized by himself, fortunately for the cause of science they have been left in charge of a successor in the person of his ardent friend and collaborator, Professor Peirce, to whose genius and industry we may confidently look for that full exposition of the work which, while it entitles him to the highest approbation of the scientific world, will render ample justice to the labors and sagacity of his lamented predecessor.

Besides having charge of the Coast Survey, Professor Bache was Superintendent of Weights and Measures, and in the exercise of this function directed a series of investigations relative to the collection of excise duties on distilled spirits, and likewise superintended the construction of a large number of sets of standard weights and measures for distribution among the several States of the Union. He was also appointed one of a commission to examine into the condition of the lighthouse system of this country, and to report upon any improvements calculated to render it more efficient. In the investigations pertaining to this subject, involving, as they do, a knowledge of a wide range of applied science, he took a lively interest, and rendered important service in the organization of the admirable system which was adopted and still remains in operation. This commission of investigation was afterward merged in the present Lighthouse Board, of which he continued a member until the time of his death.

In 1846 he had been named in the act of incorporation as one of the Regents of the Smithsonian Institution, and by successive reëlection was continued by Congress in this office until his death, a period of nearly twenty years. To say that he assisted in shaping the policy of the establishment would not be enough. It was almost exclusively through his predominating influence that the policy which has given the institution its present celebrity was, after much opposition, finally adopted. The object of the donation, it will be remembered, had been expressed in terms so concise that its import could scarcely be at once appreciated by the general public, though to the cultivators of science, to which class Smithson himself belonged, the language employed failed not to convey clear and precise ideas. Out of this state of things it is not surprising that difference of opinion should arise respecting the proper means to be adopted to realize the intentions of the founder of the institution. Professor Bache, with persistent firmness, tempered by his usual moderation, advocated the appropriation of the proceeds of the funds principally to the plan set forth in the first report of the Secretary, namely, of encouraging and supporting original research in the different branches of science. Unfortunately this policy could only be partially adopted, on account of the restrictions of the enactment of Congress, by which provision was to be made for certain specified objects. He strenuously opposed the contemplated expenditure of a most disproportionate sum in the erection and maintenance of a costly edifice; but failing to prevent this, he introduced the resolution adopted by the board as a compromise, whereby the mischief which he could not wholly avert might at least be lessened. This resolution provided that the time of the erection of the building should be extended over several years, while the fund appropriated for the purpose, being in the mean time invested in a safe and productive manner, would serve in some degree to counterbalance the effect of the great and unnecessary outlay which had been resolved on. It would be difficult for the secretary, however unwilling to intrude anything personal on this occasion, to forbear mentioning that it was entirely due to the persuasive influence of the Professor that he was induced, almost against his own better judgment, to leave the quiet pursuit of science and the congenial employment of college instruction to assume the laborious and responsible duties of the office to which, through the partiality of friendship, he had been called. Nor would it be possible for him to abstain from acknowledging with heartfelt emotion that he was from first to last supported and sustained in his difficult position by the fraternal sympathy, the prudent counsel, and the unwavering friendship of the lamented deceased.

His demeanor in the board was quiet and unobtrusive, and his opinions sought no support in elaborated or premeditated argument; but when a topic likely to lead to difficulty in discussion was introduced, he seldom failed, with that admirable tact for which he was always noted, to dispose of it by some suggestion so judicious and appropriate as to secure ready acquiescence and harmonious action. The loss of such a man in the councils of the Institution, when we consider the characteristics which it has been our aim to portray, must, indeed, be regarded as little less than irreparable.

As a vice-president of the United States Sanitary Commission his influence was felt in selecting proper agents, and suggesting efficient means for collecting and distributing the liberal contributions offered for ameliorating the condition of our soldiers during the war. But the services which he rendered the Government during the recent struggle were not confined to this agency, or to the immediate operations of the Coast Survey. He was called into consultations to discuss plans of attack on the part of the Navy, and for its coöperation with the Army. He acted also as a member of a commission to which various projects, professing to improve the art of war, were referred, and in this capacity it is not too much to say that his judicious counsel contributed to save the Government millions of dollars by preventing the adoption of plausible though impracticable propositions from which nothing but failure and loss could have resulted.

One of the last acts of his life was an exemplification of the devoted affection which he had always borne to his native city, whither it was his cherished intention to return when he should be at last released from official duty. At the request of the Governor of Pennsylvania, although overwhelmed with other public labors, he planned lines of defences for Philadelphia, and to a certain extent personally superintended their construction. Unaccustomed for many years to direct exposure to the sun, this work proved too much for his physical strength and brought on the first indications of that malady which terminated his life. Though apparently of a vigorous constitution, and capable, under the excitement of official life, of bearing an unusual amount of bodily fatigue, yet he was subject at intervals to "sick headache," a disease which seems to have been hereditary, and which perhaps conspired with other causes in terminating his useful and distinguished career. Previous to the war he had spent the warmer part of each summer in a tent, at some point of the primary triangulation of the survey, whence he directed the various parties in the field by correspondence; and as the point was usually at the top of a mountain, or at some elevated position, from which other stations of the survey could be seen, he did not want for invigorating air. With this, and the exercise of measuring angles, he laid in a store of health sufficient to enable him to carry on without interruption the arduous duties of the remaining portion of the year. But after the commencement of the war his presence was continually required in Washington to give advice and information as to military and naval operations, and to attend the meetings of the scientific commission to which we have previously referred. He was, therefore, no longer able to avail himself of the recuperating influence of mountain air, and in view of this his valuable life may be said to have been one of the sacrifices offered for the preservation of the Union. The first indications of the insidious disease which gradually sapped the citadel of life were numbness in the fingers of his right hand, and, on one occasion, for a short time only, loss of memory. Though these symptoms gave him some uneasiness, they did not diminish his exertions in the line of his duty. Other symptoms, however, exhibited themselves, which, though awaking anxiety, did not much alarm his friends, until he was suddenly deprived, in a considerable degree, of the power of locomotion and of the expression of ideas; the result, it was supposed, of a softening of the brain. But though the power of expression was paralyzed, his memory appeared to retain all the impressions of the past, and he evidently took much pleasure in having recalled to him scenes and events of years gone by. For several months he was very anxious as to the business of the Coast Survey, and it was with difficulty he could be restrained from resuming in full the duties of his office; but, as the malady increased, his perception of external objects diminished. He took less and less interest in passing events, and finally seemed to withdraw his attention from the exterior world, with which he almost ceased thenceforth to hold any active communication. It was hoped that a voyage to Europe, through the excitements of shipboard and the revival of old associations, would be of service to him; but, notwithstanding an occasional manifestation of his wonted spirit of social and intellectual enjoyment at the encounter of a friend of former times or distinguished associate in the walks of science, he returned from a sojourn abroad of eighteen months without having experienced any permanent abatement in the progress of his malady. He lingered for a short time longer, and finally resigned his breath at Newport, Rhode Island, on the 17th of February, 1867, in the sixty-first year of his age.

It would be impossible to name an American distinguished on purely scientific grounds to whom the enlightened sentiment of his own countrymen and of foreign nations has awarded more emphatic marks of admiration and esteem. The degree of Doctor of Laws was conferred on him by the principal universities of this country, and few of our leading societies were willing to forego the honor of numbering him among their associates. He was elected in succession president of the American Philosophical Society, of the American Association for the Advancement of Science, and of the National Academy of Sciences established by Congress. Nor were foreigners less forward in acknowledging his merit. He was a member of the Royal Society of London, of the Imperial Academy of Sciences at St. Petersburg, of the Institute of France, the Royal Society of Edinburgh, the Royal and Imperial Geographical Society of Vienna, the Royal Academy of Turin, the Mathematical Society of Hamburg, the Academy of Sciences in the Institute of Bologna, the Royal Astronomical Society of London, and of the Royal Irish Academy of Dublin. In addition to these testimonies of appreciation, several medals were awarded to him by foreign governments for his distinguished services in the Coast Survey and in the cause of science generally.

The life we have here sketched is eminently suggestive, both from a philosophical and a practical point of view. It presents an unbroken series of successful efforts, with no interruptions in its sustained and constantly ascending course; all parts follow each other in harmonious continuity; and not only is each stage of its progress in advance of the one which preceded it, but it furnishes the means of education for that which succeeded. It is not merely curiosity, laudable as that might be, but a sense of the importance of the inquiry, which prompts us to ask, What were the mental and moral characteristics of the mind which produced such results? And we say intentionally, the *mind which produced these results*, for although it be true that accident has in many cases a determining influence on the fortunes of an individual, it will be clear from what precedes, or we shall have greatly failed in the task which we proposed to ourselves, that the element of casualty had but little to do with the success which crowned the life to which the question at present relates.

From long acquaintance with him and critical study of the events of his life, and the distinctive manifestations of his moral and intellectual nature, we venture, though not without hesitation, to present the following analysis of the character of one who has performed so conspicuous a part, and in whose memory so many are deeply interested.

Alexander Dallas Bache possessed, or we may perhaps say originally inherited, a mind of strong general powers, with no faculty in excess or in deficiency, but, as a whole, capable of unusual expansion or development in any direction which early training or the education of life might determine. He also possessed strong passions, which, instead of exerting an unfavorable effect on his character by their indulgence, became, under the restraining influence to which they were in due season subjected, a reserved energy, as it were, ready to manifest itself spontaneously and at any time in the vindication of truth and justice. He was likewise endowed with a power of *will* which, controlling all his faculties and propensities, rendered them subservient to those fixed purposes which had once received the sanction of his deliberate judgment. Eminent also among his characteristics, and perhaps most conspicuous of all, was the social element of refined humanity, a regard for his fellow-man, which craved as an essential want of his nature fraternal sympathy, not only with those within the wide circle of his daily associations, but with those from whom he could expect no reciprocation of the sentiment, the entire brotherhood of mankind. These characteristics, with a nice preception of right and a conscience always ready to enforce its mandates, are, we think, sufficient to explain the remarkable career we have described.

They were perhaps indicated by himself, though with an admission not to be accepted without some reserve, in a conversation with the writer of this sketch in reference to his entrance at West Point. "I knew," he said, "that I had nothing like genius, but I thought I was capable by hard study of accomplishing something, and I resolved to do my best, and if possible to gain the approbation of the teachers, and, above all, to make myself loved and respected by my classmates."

To illustrate the progressive development of the individual traits of his character, we may be allowed to dwell for a moment on a few analytical details. The early period of his life, including that which preceded his first call to Philadelphia, was almost wholly devoted to the improvement of the mechanical, or the "doing" faculties of his mind, and but little attention was given to invention, or the exercise of original thought. His final examination at the Academy, perfect as it was in its kind, only exhibited his capacity for the acquisition of knowledge, not the power to originate or apply it. When his efforts were first turned in the latter direction, he evinced, as I well remember, no especial aptitude for it that would indicate future success; but in a short time, and under the stimulus of the associations into which he was thrown in Philadelphia, the faculties of investigation and of generalization were rapidly developed, and, had he not been partially turned aside from such pursuits, I doubt not that he would have still more highly distinguished himself in the line of experimental research. Again, the change in the circumstances and relations of his life produced by his election to the presidency of Girard College introduced him to a familiarity with an entirely new class of ideas, which served to exercise and expand another faculty of his mind, that, namely, which observes and appreciates moral truths, though without impairing his aptitude for physical research. In like manner, his foreign mission with reference to popular education, by bringing him into intimate and friendly association with minds of the first order in the principal cities of Europe, afforded him an opportunity for enlarging the sphere of his sympathies, as well as of studying men under a great variety of social and mental peculiarities.

Again, his long residence and high social position at the seat of Government, his intimate acquaintance and friendly intercourse with statesmen and politicians, imbued him with a thorough knowledge of the working of the Government, such as few have ever possessed, while his exertions to sustain the Coast Survey and improve its condition served to call into active operation his power to appreciate character, to discern motives, and, therefore, to convince, persuade, and control men. His ability in this latter respect was remarkable; a personal interview with an opponent of the survey scarcely ever failed to convert perhaps an active enemy into an influential friend. His success in this respect often astonished those who frequently harassed Congress with propositions covertly designed to promote their own interest at the expense of public utility; hence the exclamation was not unfrequently heard, "Bache is certainly a wonderful manager." If that which is unusual constitutes an element of wonder, then the exclamation was not without truth, though not in the sense of those by whom it was uttered, for he never advocated any measure that was not just, expedient, and proper, either as concerned the interests of the country or the welfare of his species.

On the whole, if we would seek the real secret of his influence over his fellow-men, it would be found, no doubt, to have consisted in the singular abnegation of self which pervaded his whole conduct; his great practical wisdom, his honesty of purpose, and his genial though quiet and unobtrusive manner. In the exercise of these characteristics, he was so far from the least appearance of dissimulation, that no one ever approached him without feeling that it was equally impossible to doubt the purity of his intentions as it was to elude the penetration of his quiet but thorough scrutiny. His calmness served as a shield from within and without; and as a guard against himself as well as a protection against others. It enabled him to weigh the motives and observe the character of those who consulted him with the view of securing his influence or gaining his patronage. His genial nature enabled him to descend gracefully from the heights of science and to enter fully and frankly into the feelings of any company with which he might be thrown. In this he was aided by a playfulness of fancy and a quiet humor which banished any reserve that might have been produced by a knowledge of his superior talents and attainments. He was, though by no means gifted with those attractions of person which influence at first sight, a favorite with all ages, and particularly with the sex whose discrimination of character is said to be least fallible. It seems almost superfluous to say of such a man that his friendship was open and unwavering, that his confidence once bestowed could be shaken by no mere difference of opinion or conflict of personal interests. Severe to himself under the responsibility of duty, and in the punctual observance of his engagements, his indulgence was reserved for the weak and the erring. Though his outer life was free from disappointments or rever s, and though he walked as it were in perpetual sunshine, all was not so within. Besides the anxiety and solicitude incident to the responsible duties of his position, occasions of trial and profound sorrow were not spared him. He was called to mourn the untimely loss of a beloved brother, who fell a victim to his zeal for the professor's service in the survey of the Gulf Stream; of another brother, the youngest and last, also an officer of the Navy, and a general favorite, who was drowned on the coast of California; and lastly of a sister, whom he had adopted and cherished as a child. In these seasons of affliction he found consolation in the steadfast convictions of religious faith. Nurtured in the forms and principles of the Episcopal Church, he was a devout worshipper in the sanctuary, though not bigoted in his attachment to the peculiar ordinances of that communion. He fully recognized the union of science and religion, and held with unwavering constancy the belief that revelation, properly interpreted, and science, rightly understood, must ultimately join in perfect accord in reference to the great truths essential to the well-being of man.

As an evidence of his high appreciation of abstract science derived from original investigation, he left his property in trust to the National Academy of Sciences, the income to be devoted to the prosecution of researches in physical and natural science by assisting experimentalists and observers, and the publication of the results of their investigations.

I here close this imperfect sketch, in which I am conscious of having passed in silence many admirable traits of character and conduct, and of having very inadequately portrayed others, with the remark that, though our companion and brother has departed, his works and his influence still remain to us; that, sorrow as we must for his loss, we can still recall with pride and satisfaction the example he has left us of all that, in heart, in spirit, and in life, the true man of science ought to be.

The following is a list of the published scientific papers of Alexander Dallas Bache, copied from the appendix to an address by Dr. Benjamin A. Gould, before the American Association for the Advancement of Science, August 6, 1868:—

1829—Feb. On the specific heat of the atoms of bodies. *Journ. Phila. Acad. Nat. Sci.*, vi, 141.

1830—May. On the inflammation of phosphorus in a partial vacuum. *Amer. Journ. Sci.*, xviii, 372.

1831—Mar. Report of the committee of the Franklin Institute of Pennsylvania, appointed May, 1829, to ascertain by experiment the value of water as a moving power. *Journ. Frank. Inst.*, vii, 145; viii, ix, x, etc.

1831—April. Safety apparatus for steamboats, being a combination of the fusible metal disk with the common safety-valve. *Journ. Franklin Inst.*, vii, 217; *Amer. Journ. Sci.*, xx, 317.

1831—Oct. Meteorological observations during the solar eclipse of February 12, 1831. *Trans. Amer. Phil. Soc.*, iv, 132.

1832—July. Translation of Berzelius's Essay on Chemical Nomenclature. *Amer. Journ. Sci.*, xxii, 258. *Philadelphia*, 1832.

1832—July. Notice of experiments on electricity developed by magnetism. *Journ. Franklin Inst.*, x, 66; *Amer. Journ. Sci.*, xxii, 409.

1832—Oct. Alarm to be applied to the interior flues of steam-boilers. *Journ. Franklin Inst.*, x, 217.

1832—Nov. On the diurnal variation of the magnetic needle. *Trans. Amer. Phil. Soc.*, v, 1.

1833—Mar. Elementary view of the application of analysis to reflection and refraction. An appendix to Sir David Brewster's treatise on optics. *Philadelphia*, 1833. pp. 95.

1833—July. Translation of Avogadro's memoir on the elastic force of the vapor of mercury. *Amer. Journ. Sci.*, xxiv, 286.

1833—July. Note of the effect upon the magnetic needle of the aurora borealis, visible at Philadelphia on the 17th of May, 1833. *Journ. Franklin Inst.*, xii, 5; *Amer. Journ. Sci.*, xxvii, 113.

1833—Nov. Attempt to fix the date of Dr. Franklin's observation, in relation to the northeast storms of the Atlantic States. *Journ. Franklin Inst.*, xii, 300.

1833—Dec. Report of experiments on the navigation of the Chesapeake and Delaware Canal by steam. *Journ. Franklin Inst.*, xii, 361.

1834—Jan. Observations on the disturbance in the direction of the horizontal needle, during the occurrence of the aurora of July 10, 1833. *Journ. Franklin Inst.* xiii, 1; *Amer. Journ. Sci.*, xxvii, 118.

1834—Jan. Report of the managers of the Franklin Institute, in relation to weights and measures. Presented in compliance with a resolution of the House of Representatives of the State of Pennsylvania. *Journ. Franklin Inst.*, xiv, 6; *Philadelphia*, 1834.

1834—June. Analysis of some of the coals of Pennsylvania (made jointly with Professor H. D. Rogers). *Journ. Phila. Acad. Nat. Sci.*, vii, 158.

1834—Oct. On the variation of the magnetic needle. *Amer. Journ. Sci.*, xxvii, 385.

1834—Nov. Observations to determine the magnetic dip at Baltimore, Philadelphia, New York, West Point, Providence, Springfield, and Albany (made jointly with Professor E. H. Courtenay). *Trans. Amer. Phil. Soc.*, v, 209.

1834—Nov. Meteoric observations on and about Nov. 13, 1834. *Amer. Journ. Sci.*, xxvii, 335; *Journ. Franklin Inst.*, xvi, 369.

1835—Jan. Note relating to the hardening of lime under water, by the action of carbonate of potassium, etc., and to the hardening of carbonate of lime in the air, by potassa and soda. *Journ. Frank. Inst.*, xv, 6.

1835—Mar. Meteorological observations made during the solar eclipse of November 30, 1834. *Trans. Amer. Phil. Soc.*, v, 237.

1835—May. Experimental illustrations of the radiating and absorbing powers of surfaces for heat, of the effects of transparent screens, of the conducting power of solids, etc. *Journ. Franklin Inst.*, xv, 303; *Amer. Journ. Sci.*, xxviii, 320.

1835—May. Replies to a circular in relation to the occurrence of an unusual meteoric display on the 13th of November, addressed by the Secretary of War to the military posts of the United States, with other facts relating to the same question. *Amer. Journ. Sci.*, xxviii, 305; *Journ. Franklin Inst.*, xvi, 149.

1835—June. Experiments on the efficacy of Perkins's steam-boilers or circulators. *Journ. Franklin Inst.*, xv, 379.

1835—July. On the comparative corrosion of iron, copper, zinc, etc., by a saturated solution of common salt. *Journ. Franklin Inst.*, xvi, 2.

1835—Nov. Inquiry in relation to the alleged influence of color on the radiation of non-luminous heat. *Journ. Franklin Inst.*, xvi, 289; *Amer. Journ. Sci.*, xxx, 16.

1835—Dec. Historical notice of a hypothesis to explain the greater quantity of rain which falls on the surface of the ground than above it. *Journ. Franklin Inst.*, xvii, 106.

1836—Jan. Observations upon the facts recently presented by Professor Olmsted in relation to meteors seen on the 13th of November, 1834. *Journ. Franklin Inst.*, xvii, 33; *Amer. Journ. Sci.*, xxix, 383.

1836—Jan. Historical note on the discovery of the non-conducting power of ice. *Journ. Franklin Inst.*, xvii, 182.

1836—Jan. Report of experiments made by the committee of the Franklin Institute of Pennsylvania, on the explosions of steam-boilers, at the request of the Treasury Department of the United States. *Journ. Franklin Inst.*, xvii, 1, 73, 145, 217, 289.

1836—Feb. Remarks on a method, proposed by Dr. Thomson, for determining the proportions of potassa and soda in a mixture of the two alkalies; with the application of a similar investigation to a different method of analysis. *Journ. Franklin Inst.*, xvii, 305.

1836—April. Notes and diagrams illustrative of the directions of the forces acting at and near the surface of the earth, in different parts of the Brunswick tornado of June 19, 1835. *Trans. Amer. Phil. Soc.*, v, 407.

1836—May. On the relative horizontal intensities of terrestrial magnetism at several places in the United States, with the investigations of corrections for temperature, and comparisons of the methods of oscillation in full and in rarefied air (jointly with Professor E. H. Courtenay). *Trans. Amer. Phil. Soc.*, v, 427.

1836—July. Proposed forms of diagrams for exhibiting to the eye the results of a register of the direction of the wind. *Journ. Franklin Inst.*, xviii, 22.

1837—May. Corresponding magnetic observations, in connection with Professor Lloyd of Dublin, to determine the relative magnetic intensity in Philadelphia, Dublin, and Edinburgh. *Proc. R. Irish Acad.*, i, 71.

1838—Aug. Note on the effect of deflected currents of air on the quantity of rain collected by a rain-gauge. *Rep. Brit. Assoc. Adv. Sci.*, 1838, ii, 25.

1839—May. Report on education in Europe, to the trustees of the Girard College for Orphans. 8vo. pp. 666. *Philadelphia*, 1839.

1839—Nov. Comparison of Professor Loomis's observations on magnetic dip with those obtained by Professor Courtenay and himself. *Proc. Amer. Phil. Soc.*, i, 146.

1839—Nov. Simultaneous magnetic observations, made in correspondence with Professor Lloyd of Dublin. *Proc. R. Irish Acad.*, i, 462; *Amer. Journ. Sci.*, xli, 212.

1840—Mar. Observations of the magnetic intensity at twenty-one stations in Europe. *Trans. Amer. Phil. Soc.*, vii, 75; *Proc. Amer. Phil. Soc.*, i, 185.

1840—Nov. Determination of the magnetic dip at Philadelphia and Baltimore. *Proc. Amer. Phil. Soc.*, i, 294.

1840—Dec. On an instrument for measuring the changes in the vertical component of the force of terrestrial magnetism. *Proc. Amer. Phil. Soc.*, i, 311.

1841—May. Diagram of the direction and force of the wind, and amount and rate of rain-fall during the severe gust of April 2, 1841. *Proc. Amer. Phil. Soc.*, ii, 56.

1841—July. On observations of the magnetic dip, made at Baltimore by Mr. Nicollet and Major Graham. *Proc. Amer. Phil. Soc.*, ii, 83.

1841—Nov. Account of the formation of cumulus cloud from the action of a fire. *Proc. Amer. Phil. Soc.*, ii, 116.

1842—Mar. Semi-annual report of the principal of the High School, and report to the controllers of the public schools. *Twenty-fourth Annual Report of Controllers of Public Schools of Philadelphia*, pp. 23, 50.

1842—April. On the application of the self-registering rain-gauge to registering the fall of snow. *Proc. Amer. Phil. Soc.*, ii, 164.

1842—July. Report of the principal of the Central High School for the year ending July, 1842. 8vo. pp. 120. *Philadelphia.*

1842—Oct. Address delivered at the close of the twelfth exhibition of American manufactures, held by the Franklin Institute.

1842—Dec. On a modification of Lloyd's induction inclinometer. *Proc. Amer. Phil. Soc.*, ii, 237.

1843—Jan. On a new dew-point hygrometer. *Proc. Amer. Phil. Soc.*, ii, 249.

1843—May. Results of two years' observations of the magnetic elements, and of the temperature, pressure, and moisture of the atmosphere at the magnetic observatory of Girard College. *Proc. Amer. Phil. Soc.*, iii, 90.

1843—May. Account of an instrument for determining the conducting power of bodies for heat. *Proc. Amer. Phil. Soc.*, iii, 132.

1843—May. Account of observations at Philadelphia and Toronto, during the magnetic disturbance of May 6, 1843, and their bearing upon the question of the kind of instruments and observations appropriate to determine such phenomena. *Proc. Amer. Phil. Soc.*, iii, 175.

1845—Feb. Report to the Treasury Department on the progress of construction of standard weights and measures. *Senate Doc.* 149, 28*th Congress*, 2*d Session.*

1847—Dec. Description of a new base apparatus used in the United States Coast Survey. *Proc. Amer. Phil. Soc.*, iv, 368.

1848—Dec. On a new method of observing transits. *Monthly Not. R. Astr. Soc.*, ix, 123; *Bull. Acad. Sci.*, *Brussels*, xvi, 313; *Astr. Nachr.*, xxviii, 273.

1849—Aug. Comparison of the results obtained in geodesy by the application of the theory of least squares. *Proc. Amer. Assoc. Adv. Sci.*, *Cambridge*, 1849, p. 102.

1849—Aug. On the progress of the survey of the coast of the United States. *Proc. Amer. Assoc.*, *Cambridge*, 1849, p. 162.

1850—Mar. Notes on the results of observations of the direction and force of the wind at the Coast Survey stations at Mobile Point and at Cat Island, Gulf of Mexico. *Proc. Amer. Assoc.*, *Charleston*, 1850, p. 50.

1850—Mar. Abstract of a communication on the recent progress of the telegraphic operations of the United States Coast Survey. *Proc. Amer. Assoc.*, *Charleston*, 1850, p. 122.

1850—Aug. Method used in the Coast Survey for showing the results of current observations. *Proc. Amer. Assoc.*, *New Haven*, 1850, p. 70; *C. S. Rep.*, 1850, p. 136.

1850—Aug. Remarks upon the meeting of the American Association at Charleston, in March, 1850. *Proc. Amer. Assoc.*, *New Haven*, 1850, p. 159.

1850—Aug. Notes of a discussion of tidal observations, in connection with the Coast Survey, made at Cat Island, in the Gulf of Mexico. *Proc. Amer. Assoc., New Haven*, 1850, p. 281; *Amer. Journ. Sci.*, xii, 341; *C. S. Rep.*, 1851, p. 127.

1851—May. Current chart of New York Bay, from observations in the Coast Survey. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 43.

1851—May. Comparison of curves showing the hourly changes of magnetic declination at Philadelphia, Toronto, and Hobarton from April to August, and from October to February, and for March and September. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 62.

1851—May. On the determination of the velocity of sound by the method of coincidences. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 75.

1851—May. Notes on the use of the zenith telescope in determining latitudes in the Coast Survey by Talcott's method, and on the reduction of the observations. *Proc. Amer. Assoc., Cincinnati*, 1851, p. 151; *Amer. Journ. Sci.*, xiv, 191.

1851—Aug. Additional notes of a discussion of tidal observations made in connection with the Coast Survey at Cat Island, Louisiana. *Proc. Amer. Assoc., Albany*, 1851, p. 94; *Amer. Journ. Sci.*, xiv, 346; *C. S. Rep.*, 1852, p. 111.

1851—Aug. Notes on the tides at Sand Key, near Key West, Florida. *Proc. Amer. Assoc., Albany*, 1851, p. 138.

1851—Aug. Address on retiring from the duties of president of the American Association for the Advancement of Science. *Proc. Amer. Assoc., Albany*, 1851, p. 41.

1852—Mar. Report on the harbor of Charleston, South Carolina (as chairman of a committee).

1853—July. On the tides at Key West, Florida, from observations made in connection with the United States Coast Survey. *Proc. Amer. Assoc., Cleveland*, 1853, p. 32; *Amer. Journ. Sci.*, xviii, 305; *C. S. Rep.*, 1853, p. 71.

1853—July. On the tides of the western coast of the United States, from observations at San Francisco, California, in connection with the United States Coast Survey. *Proc. Amer. Assoc., Cleveland*, 1853, p. 42; *Amer. Journ. Sci.*, xxi, 1; *C. S. Rep.*, 1853, p. 77.

1854—May. Preliminary determination of co-tidal lines on the Atlantic coast of the United States, from the Coast Survey tidal observations. *Proc. Amer. Assoc., Washington*, 1854, p. 107; *Amer. Journ. Sci.*, xxi, 14; *C. S. Rep.*, 1854, p. 147.

1854—May. Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, on the Pacific coast of the United States, from observations in connection with the Coast Survey. *Proc. Amer. Assoc., Washington*, 1854, p. 161; *Amer. Journ. Sci.*, xxi, 10; *C. S. Rep.*, 1854, p. 152.

1854—May. On the distribution of temperature in and near the Gulf Stream, off the coast of the United States, from observations made in the Coast Survey. *Proc. Amer. Assoc., Washington*, 1854, p. 134; *Amer. Journ. Sci.*, xxi, 29; *C. S. Rep.*, 1854, p. 156.

1854—June. Second report on the harbor of Charleston, South Carolina.

1855—Feb. Discussion of observations for the isodynamic, isogonic, and isoclinal curves of terrestrial magnetism, on and near the line of the boundary survey between the United States and Mexico, made in 1849–1852, under the order of W. H. Emory, and combined with observations at San Francisco, California, and Dollar Point (E. Base), and Jupiter, Texas. *Mem. Amer. Acad. Arts and Sci.*, v, 1872.

1855—Aug. Approximate co-tidal lines of the Pacific coast of the United States, from observations in the United States Coast Survey. *Proc. Amer. Assoc., Providence*, 1855, p. 144; *C. S. Rep.*, 1855, p. 338.

1855—Aug. Notice of the tidal observations made on the coast of the United States, on the Gulf of Mexico, with type-curves at the several stations, and their decomposition into the curves of diurnal and semi-diurnal tides. *Proc. Amer. Assoc., Providence*, 1855, p. 152; *Amer. Journ. Sci.*, xxi, 128; *C. S. Rep.*, 1855, p. 346.

1855—Aug. Notice of earthquake waves on the western coast of the United States on the 23d and 25th of December, 1854. *Proc. Amer. Assoc., Providence*, 1855, p. 153; *Amer. Journ. Sci.*, xxi, 37; *C. S. Rep.*, 1855, p. 342.

1855—Dec. Report to New York harbor commissioners, on surveys of New York Harbor.

1856—Jan. Annual Address before the American Geographical Society, being a paper upon the Gulf Stream. *Bulletin Amer. Geogr. Soc.*, ii, 94.

1856—Aug. Approximate co-tidal lines of diurnal and semi-diurnal tides of the coast of the United States on the Gulf of Mexico. *Proc. Amer. Assoc., Albany*, 1856, p. 168; *Amer. Journ. Sci.*, xxiii, 12; *C. S. Rep.*, 1856, p. 252.

1856—Aug. On the general distribution of terrestrial magnetism in the United States, from observations made in the United States Coast Survey and others (in connection with Mr. J. E. Hilgard). *Proc. Amer. Assoc., Albany*, 1856, p. 187; *Amer. Journ. Sci.*, xxvi, 1; *C. S. Rep.*, 1856, p. 209.

1856—Aug. Observations to determine the cause of the increase of Sandy Hook, made by the Coast Survey for the commissioners on harbor encroachments. *Proc. Amer. Assoc., Albany*, 1856, p. 171; *Amer. Journ. Sci.*, xxiii, 16; *C. S. Rep.*, 1856, p. 263.

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1856—Aug. Notes on the progress made in the Coast Survey in prediction-tables for the tides of the United States coast. *Proc. Amer. Assoc., Albany*, 1856, p. 166; *C. S. Rep.*, 1856, p. 249.

1856—Oct. Anniversary address before the American Institute of the city of New York, during the twenty-eighth annual fair. *New York*, 1857, pp. 60.

1856—Dec. Report to New York harbor commissioners on the progress of the survey of New York harbor.

1856—Dec. Notes on the winds of the coast of the United States on the Gulf of Mexico. *C. S. Rep.*, p. 272.

1856—Dec. Report of Superintendent of Weights and Measures.

1857—Aug. Notice of the determination of the longitude of Fernandina, Amelia Island, Florida, by means of chronometer exchanges from Savannah, Georgia (in connection with Mr. C. A. Schott). *Proc. Amer. Assoc., Montreal*, 1857, p. 166; *C. S. Rep.*, 1857, p. 314.

1857—Aug. On the heights of the tides of the Atlantic coast of the United States, from observations in the Coast Survey. *Proc. Amer. Assoc., Montreal*, 1857, p. 175; *Amer. Journ. Sci.*, xxv, 47; *C. S. Rep.*, p. 342.

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1857—Aug. Notes on the measurement of the base of the primary triangulation of the eastern section of the coast of the United States, on Epping Plains, Maine. *Proc. Amer. Assoc., Montreal*, 1857, p. 160; *Amer. Journ. Sci.*, xxv, p. 58; *C. S. Rep.*, 1857, p. 302.

1857—Dec. Report relative to the New York harbor survey. *U. S. Senate Doc.*, 1858, No. 16.

1858—May. On a supposed personal equation in the use of the zenith telescope, for determining latitudes by Talcott's method. *Proc. Amer. Assoc., Baltimore*, 1858, p. 14; *C. S. Rep.*, 1858, p. 184.

1858—May. On the tidal currents of New York Bay, near Sandy Hook. *Proc. Amer. Assoc., Baltimore*, 1858, p. 80; *Amer. Journ. Sci.*, xxvi, 334; *C. S. Rep.*, 1858, p. 197.

1858—July. Defence of Dr. Gould, by the scientific council of the Dudley Observatory (in connection with Professors Joseph Henry and Benj. Peirce). *Albany*, 1858, pp. 91.

1859—Feb. Address before the Alumni Association of the Central High School. *Philadelphia*, 1859.

1859—June. Address in tribute to the memory of Humboldt. *The Pulpit and Rostrum*, No. 6.

1859—Aug. General account of the results of the discussion of the declinometer observations, made at Girard College, Philadelphia, between the years 1840 to 1845, with special reference to the eleven-year period. *Proc. Amer. Assoc., Springfield*, 1859, p. 248.

1859—Aug. Gulf-Stream explorations. Third memoir. Distribution of temperature in the water of the Florida Channel and Straits. *Proc. Amer. Assoc., Springfield*, 1859, p. 257; *Amer. Journ. Sci.*, xxix, 199; *C. S. Rep.*, 1859, p. 306.

1859—Nov. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845, Part I. Investigation of the eleven-year period in amplitude of the solar diurnal variation, and of the disturbances of the magnetic declination. pp. 22. *Smiths. Contrib. to Knowledge*, vol. xi, art. iv; *C. S. Rep.*, 1859, p. 278.

1860—Aug. Lecture on the Gulf Stream. *Proc. Amer. Assoc., Newport*, 1860, p. xlix; *Amer. Journ. Sci.*, xxx, 313; *C. S. Rep.*, 1860, p. 165.

1860—Aug. General account of the results of Part II of the discussion of the declinometer observations made at the Girard College, Philadelphia, between 1840 and 1845, with special reference to the solar diurnal variation and its annual inequality. *Proc. Amer. Assoc., Newport*, 1860, p. 74; *Amer. Journ. Sci.*, xxxi, 197.

1860—Aug. Abstract of a discussion of the influence of the moon on the declination of the magnetic needle, from the observations at the Girard College. *Proc. Amer. Assoc., Newport*, 1860, p. 83; *Amer. Journ. Sci.*, xxxi, 98.

1860—Sept. Observations of the solar eclipse of 1860, July 18, at the Coast Survey station, Gunstock Mountain. *Astron. Journ.*, vi, 157.

1862—June. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845, Part II. Investigation of the solar diurnal variation of the magnetic declination and its annual inequality, pp. 28. *Smiths. Contrib. to Knowl.*, vol. xiii, art. v; *C. S. Rep.*, 1860, p. 293.

1862—June. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845, Part III. Investigation of the influence of the moon on the magnetic declination, pp. 16. *Smiths. Contrib. to Knowl.*, vol. xiii, art. vi; *C. S. Rep.*, 1860, p. 312.

1862—Sept. Abstract of a discussion of the horizontal component of the magnetic force, from observations made at the Girard College observatory, Philadelphia, in the years 1840 to 1845. *Amer. Journ. Sci.*, xxxiv, 261.

1862—Nov. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845, second section, comprising Parts IV, V, VI. Horizontal force, investigation of the ten or eleven year period, and of the disturbances of the horizontal component of the magnetic force; investigations of the solar diurnal variation and of the annual inequality of the horizontal force, and the lunar effect on the same, pp. 78. *Smiths. Contrib. to Knowl.*, vol. xiii, art. viii; *C. S. Rep.*, 1862, p. 161.

1862—Nov. Abstract of an investigation of the solar diurnal variation of the annual inequality of the horizontal component of the magnetic force, from observations made at the Girard College observatory, between 1840 and 1845. *Amer. Journ. Sci.*, xxxiv, 373.

1862—Nov. Abstract of a discussion of the influence of the moon on the horizontal magnetic force, from observations made at the Girard College observatory, in the years 1840 to 1845. *Amer. Journ. Sci.*, xxxiv, 381.

1862—Dec. Additional researches on the co-tidal lines of the Gulf of Mexico. *C. S. Rep.*, 1862, p. 126.

1863—Jan. Eulogy on Hon. James Alfred Pearce. *Annual Report of Regents Smithsonian Institution for* 1862, p. 100.

1863—May. Abstract of results of a magnetic survey of Pennsylvania and parts of adjacent States in 1840 and 1841, with some additional results of 1843 and 1862, and a map. *Amer. Journ. Sci.*, xxxv, 359; *C. S. Rep.*, 1862, p. 212.

1863—Oct. Records and results of a magnetic survey of Pennsylvania and parts of adjacent States in 1840 and 1841, with some additional records and results of 1834, 1835, 1843, and 1862, and a map, pp. 88. *Smiths. Contrib. to Knowl.*, vol. xiii, art. viii.

1864—May. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845, third section, comprising Parts VII, VIII, IX. Vertical force. Investigation of the eleven (or ten) year period, and of the disturbances of the vertical component of the magnetic force, and appendix on the magnetic effect of the aurora borealis; with an investigation of the solar diurnal variation, and of the annual inequality of the vertical force, and of the lunar effect on the vertical force, the inclination and total force, pp. 72. *Smiths. Contrib. to Knowl.*, vol. xiv, art. ii; *C. S. Rep.*, 1863, p. 156.

1865—Jan. Discussion of the magnetic and meteorological observations made at the Girard College observatory, Philadelphia, in 1840 to 1845; fourth section, comprising Parts X, XI, XII. Dip and total force. Analysis of the disturbances of the dip and total force; discussion of the solar diurnal variation and annual inequality of the dip and total force; and discussion of the absolute dip, with the final values for declination, dip, and force, between 1841 and 1845, pp. 44. *Smiths. Contrib. to Knowl.*, vol. xiv, art. iii; *C. S. Rep.*, 1864, p. 183.

1844 to 1863. Annual reports of the progress of the United States Coast Survey.

1844 to 1848. Annual reports of Superintendent of Weights and Measures.

1855 to 1864. Tide tables for the use of navigators, prepared from the Coast Survey observations, annually.

Also, the following reports concerning harbors, jointly with Messrs. Totten and Davis:—

1853—Mar. Report upon Cape Fear River and harbor.

1854—Oct. Report of Portland harbor commission.

1855—Mar. Second report of the commissioners on Portland harbor.

1855—Dec. Report of advisory council of the New York harbor commission. *New York Assembly Doc.*, 1856, No. 8.

1856—July. Report of the advisory council of the New York harbor commission, recommending certain lines in the East and North Rivers, and in Brooklyn. *New York Senate Doc.*, 1857, No. 40, p. 107.

1856—July. Report of the advisory council of the New York harbor commission on Gowanus Bay and its improvements. *New York Senate Doc.*, 1857, No. 40, p. 118.

1856—Sept. Report of the advisory council of the New York harbor commission on the Hell Gate Passage, regarded as a channel of approach to New York harbor. *New York Senate Doc.*, 1857, No. 40, p. 137.

1856—Oct. Second general report of the advisory council to the harbor commissioners, on lines in New York harbor. *New York Senate Doc.*, 1857, No. 40, p. 81.

1856—Dec. Report of the advisory council to the commissioners on harbor encroachments of New York, in regard to safe and commodious anchorages in New York harbor, for the purposes of the quarantine of vessels. *New York Senate Doc.*, 1857, No. 40, p. 132.

1856—Dec. Report of the advisory council to the New York harbor commissioners upon Harlem River and Spuyten Duyvil Creek. *New York Senate Doc.*, 1857, No. 40, p. 151.

1857—Feb. Report of the advisory council of lines for the East River, for the shore of Long Island, and the east shore of Staten Island. *New York Senate Doc.*, 1857, No. 126, p. 9.

1857—Mar. Report of the advisory council to the New York harbor commissioners upon the comparative map of New York Bay and harbor, and its approaches, prepared by the Coast Survey in March, 1857. *New York Senate Doc.*, 1857, No. 126, p. 12.

1860—Mar. Preliminary reports of commissioners on Boston harbor. *Boston City Doc.*, 1860, No. 37.

1860—Dec. Second report of United States commissioners on the condition of Boston harbor. *Boston City Doc.*, 1860, No. 97.

1860—Dec. Special report of the United States commissioners on Boston harbor, on the relation of Mystic Pond and River to Boston harbor. *Boston City Doc.*, 1861, No. 12.

1860—Dec. Report of the advisory council of the joint committee of the Massachusetts legislature on the subject of a ship-canal to connect Barnstable Bay and Buzzard's Bay. *Mass. Pub. Doc.*, 1864, No. 41.

1861—Sept. Fourth report of the United States commissioners on Boston harbor. *Boston City Doc.*, 1861, No. 62.

1861—Sept. Fifth report of the United States commissioners on Boston Harbor. *Boston City Doc.*, 1861, No. 63.

1863—April. Sixth report of the United States commissioners on Boston harbor. *Boston City Doc.*, 1863, No. 53.

1864—Mar. Seventh report of the United States commissioners on Boston harbor. *Boston City Doc.*, 1864, No. 33.

1864—Mar. Eighth report of the United States commissioners on Boston harbor. *Boston City Doc.*, 1864, No. 34.

MEMOIR

OF

JOHN H. ALEXANDER.

1812 - 1867.

BY

J. E. HILGARD.

READ BEFORE THE ACADEMY, APRIL 18, 1872.

BIOGRAPHICAL MEMOIR OF JOHN H. ALEXANDER.

ONCE more the Academy meets to inscribe on its memorial-tablets the name of one of its original members, named in the charter of its organization. Death has been busy in its ranks—within four years from the time of its creation six names have passed to the record of the departed. Some of these, it is true, went in the fulness of years and honors, but others, being still in the vigor of life, might have added much to their services to science and their country, had they been spared. Of the latter number was our late fellow-member, whose life and works we now briefly commemorate.

JOHN HENRY ALEXANDER was born on the 26th of June, 1812, in Annapolis, then as now the seat of government of the State of Maryland. He was the youngest child of William Alexander and Mary Stockett. The father was a member of a Scotch-Irish family, settled in and about Belfast, who having come to America while still a youth, at the close of the struggle for independence, established himself as a merchant in the city of Annapolis, which with its deep harbor and productive vicinage, was a place of considerable trade—in those days, when Baltimore had not yet absorbed all the shipping business of Maryland. The Stockett family, into which he married, came over in 1642, and settled on South and West Rivers, where the estates remain in possession of the family to the present day.

Young Alexander was thus emphatically a son of the State to which he ever adhered, and whose greatness he sought to advance, often before the time had come when the community could appreciate the benefits that were to flow from his plans.

While he was still in childhood, his father died, leaving but scanty provision for the family. The mother, represented as a lady of remarkable beauty and strength of character, lovely and winning in mind and heart, carefully trained her youngest child, doubtless imparting to his character much of her own refinement and sensibility.

He received his classical education at St. John's College, in his native town, where he took his degree at the age of fourteen, dividing the first honors with his life-long friend, now the Rev. Dr. William Pinkney, Rector of the Church of the Ascension in Washington, to whom the present biographer is largely indebted for facts and traits of character, which his own acquaintance, limited to later years, could not have readily supplied. Speaking of these early days of Prof. Alexander, his friend says:—

"We passed out of the college halls together, and entered a law office. For four years we read, and walked, and talked together; and then began his careful examination of history, and the great principles of the law, as expounded by its masters. Nothing escaped him, that a youth of his years could comprehend. It is my firm conviction, that had he continued at the bar, he would have soon reached the first ranks of his profession. For although he possessed not the gift of oratory, and would probably not have made a brilliant pleader, he had those peculiar powers, clearness of statement, skill of analysis, concentration and amplification, earnest gravity and wonderful fluency, which would have commanded the respect of courts, and the confidence of juries. He was rich in resources, adroit in argument, ready in retort, and sparkling with wit. No man, who ever encountered him in one of those off-hand debates that spring up in private conversation, could fail to discover that it was necessary to call up his reserves, and keep the column of his ideas in order. He possessed singular self-control, and never allowed passion to obscure his reason, or excitement to throw him off his guard."

About this time began the development of the modern system of transportation, and of the many applications of science to the arts, relieving the labor of man, and diminishing the obstacles of time and space. Young Alexander, perceiving the great influence which railroads and steamships, and the development of the stores of coal and iron laid up in the earth, were to have on the future of the country, turned aside from the legal career, and devoted himself to applied science.

His first work was in connection with surveys for the Susquehanna Railroad, now part of the Northern Central, but he soon turned his attention to the project for a complete topographical map of the State of Maryland, in conjunction with a geological survey. Having urged the matter upon the attention of the legislature, he was appointed before he had completed his twenty-first year, to make examinations preliminary to a general survey of the State, together with Prof. Julius T. Ducatel, who had charge of the geology.

The plan which they submitted was approved, and the offices of Topographical Engineer and Geologist were created in February, 1834, to which Alexander and Ducatel were appointed. The means provided were, however, small, and the work progressed but slowly. A large volume of annual reports, made between 1833 and 1840, attests the faithful efforts made to produce valuable results and to arouse the interest of the people in the development of the agricultural and mineral wealth, and the lines of communication in the State.

Prof. Alexander's plan was to make a complete trigonometrical survey of the State, which should furnish the basis for an accurate topographical and geological map. By making a trigonometrical reconnoissance, he was enabled within four years to construct a map sufficient for the representation of the geology, but in his view only a basis upon which to plan a more elaborate work of geodesic accuracy. This he proposed to execute in connection with the Coast Survey, and he postponed entering upon it, until that work should have reached Maryland, in order to avail himself of its accurate fundamental positions. Meantime the geological examinations were continued by Prof. Ducatel, and the more immediate results of economic value were published in annual reports, illustrated by maps of the several counties, prepared by Prof. Alexander.

When, in 1841, that stage of the work was reached at which a general scientific report on the geology of the State could have been entered upon, and when the trigonometrical survey was about to be commenced, its support by the State was withdrawn—partly in consequence of the depressed condition of its finances, partly from the prevalence of a narrow utilitarian view—and the new map of Maryland has remained unfinished, as well as its geology. It is due to Prof. Alexander to note, that although he continued to hold the commission as Topographical Engineer of the State, from 1837 to 1841, he drew no part of the salary attached to it.

During these years he gave much of his time to the opening of the bituminous coal beds in Allegany County, and founded the George's Creek Coal and Iron Company, of which he was President from 1836 to 1845, in which capacity he visited Europe in 1839, with a view of enlisting foreign capital in the enterprise. While engaged in these pursuits he published, in 1840, a volume entitled "Contributions to a History of the Metallurgy of Iron," which, with his habitual thoroughness, is in fact a complete treatise on the subject up to his day. It was followed by a supplement in 1842.

To meet a want very generally felt by the practical engineer in our country, in those days when we had no schools of engineering and when the rapid development of the country called for a great number of surveyors and engineers, he edited with copious additions and adaptations to our special wants, "Simms' Treatise on Mathematical Instruments used in Surveying, Leveling, and Astronomy." This work has passed through several editions, and remains to this day an excellent standard of reference. Among valuable original devices in this branch of science was that of a new form of barometer, specially adapted for the purpose of measuring altitudes, which is described in a paper printed in the *Amer. Journ. of Sciences*, vol. xlv, 1843. In the list of publications appended to this memoir will be found several papers on cognate subjects, contributed by him.

The subject of Standards of Weight and Measure early attracted Dr. Alexander's attention. He was in constant communication with the late Professor Hassler, Superintendent of the Coast Survey, under whose direction copies of the United States Standards were constructed for delivery to the several States, with the view to securing uniformity throughout the country. Upon the completion of the same, Dr. Alexander urged upon the Legislature of his own State the propriety of furnishing copies thereof to each county, and was, in 1842, charged with their construction and verification. His report "On the Standards of Weight and Measure for the State of Maryland," made in 1845, is a work of great research, and exhibits strikingly the thoroughness, accuracy, and ingenuity which he brought to bear on every subject that he undertook to deal with.

It contains a disquisition on the origin of the Anglo-Saxon measures, with a digest of all legislation had in reference to the matter in England from the earliest times, and subsequently in the United States. This historical statement must have cost immense research, and is invaluable in the latter part, by giving an account of frequent Congressional inquiry and Committee reports, which, not having resulted in legislation, can be found only by a thorough examination of the Journal of both Houses of Congress. Dr. Alexander's comment on a Committee Report of 1819 may be quoted as illustrating his own views in regard to proposed changes that have been much canvassed in latter years. He says: "This report is a model of calmness and conservatism: too much learning had not confused, nor too wearied reflection led astray. It is easy to see, too, from its tone, as well as that of the Senate resolution just quoted, how the public mind was settling down in aversion to a violent change: what had been found hard of acceptance in 1790, among a people of less than four millions, was now, with a population not far short of ten millions, grown to be nearly impossible."

In the experimental portion of Dr. Alexander's work in constructing these standards, his method of determining the cubical temperature-factor of the metal employed by comparing it with that of water, through the weight of the water displaced from a glass vessel by the effect of heat, with and without the metal in question being immersed in it, deserves special mention. With the aid of an accurate balance he was thus able to get very satisfactory results, that otherwise could only have been obtained by expensive apparatus not at his command.

He subsequently published (*Am. Journ. Sci.*, vol. xvi., 1853), a discussion of Mr. Hassler's experiments on the dilatation of water by heat, which were not readily accessible to men of science. His introductory remarks to that paper may fitly find a place here, both as illustrating his own style and character, and as a tribute to a geometer whose life-memoir has not yet been written as it deserves to be.

"The late Mr. Hassler enjoyed, during his lifetime, a high reputation; but one founded, it would appear, at least in this country, more upon the prestige of his manifest and presumed intellectual and moral faculties, than upon any just knowledge or estimate of his special achievements in science or art. It is true that these faculties were both large and well defined, and they had a scope for their exhibition, sometimes, more favorable to the interest of the spectator than the ease and comfort of the actor. He was undaunted, diligent, patient, self-reliant; no man feared an adversary less, or loved friends more; sympathetic, too, and (for which credit was not generally given him) tender-hearted; still his stern self-command enabled him for many years to fold his robe with a certain grace over wounds of soul and body, so deep and sore as to have put out of the heads of many others, who yet think themselves strong men, all idea of the dignity of sorrow. Intellectually, also, nature had been bountiful to him, and under his finely shaped cranium had placed a network of brain, active in perception, and of firm retention. All the organism for a geometer was there: and wit and humor, too, with a spice of dogmatism, that, like carbonic acid in certain wines (itself an irrespirable gas), only served to make them more racy and *montants.* Unfamiliar people were apt to suppose that this free acidity predominated normally; but the fact was, that his dogmatism arose out of his disgust at all pretence, and it was always manifested in proportion to the difference between the reality, and the pretension in any person or thing that exhibited the latter. He was essentially a man of truth; assumption of any kind disgusted him; while to assumption without a basis (or what is commonly called humbug) he was never merciful, but visited it with all the weight of logic and all the sharpness of sarcasm. Those who knew him, knew that he could be both heavy and sharp.

"But to draw traits of character was by no means the object of this memoir; what has been said, has slipped from my pen spontaneously. It is true, that honored by the intimacy of Mr. Hassler, and even bound by a sort of half promise (for in the mathematical probabilities of life, there was every chance of my being long his survivor), I should years since, had the means been at my disposal, have endeavored to do justice to his memory by an account of the events he had mixed in, of the services he had rendered toward the stabilitation and diffusion of knowledge, and of the methods, which he partly originated, and partly combined, for divers researches of science."

When after the death of Mr. Hassler, in 1843, Prof. Bache, our late lamented President, was appointed to the superintendency of the Coast Survey, Dr. Alexander's previous acquaintance with that distinguished scientist soon ripened into friendship, and he ever held an esteemed place as *amicus curiae* in the counsels of the Coast Survey and Standards Department.

While engaged in the construction of the State standards, he collected data for a work entitled, "A Universal Dictionary of Weights and Measures, ancient and modern" (Baltimore, 1850), which is one of the most complete and exact works of the kind ever published, and must ever continue to hold a high rank as a work of reference.

A pamphlet entitled, "International Coinage for Great Britain and the United States," first printed in 1855, as a basis for action by Congress, and subsequently reprinted in England (Oxford, 1857), shows the mature and analytic consideration he had given to the subject under discussion. His aim was to equalize the pound sterling and the half-eagle—a measure which would be of infinite convenience to the two nations, if the temporary inconvenience of a change could be tided over. His concluding paragraphs may be here quoted:—

"It is to such an end of simplification and harmony that all which has been here written is aiming. Not that the aim could not by others have been better expressed, or, when time is riper, or by happier effort even now, been better reached; but mainly as an indication of a method, resting upon principles unquestionable, by which a great and useful result may be conveniently attained.

"All violent changes are here avoided. That one, the hardest of all to be effected in great national masses, the change of *name* (which is, in its degree, a change of language, and so of thought, which in general finds life but in language), is here neither necessary nor even contemplated. Quietly, with prudent management—almost without management at all—the existing systems blend with and melt away in the new one, whose convenience in the mint and in the market there is no need of experience to affirm; until, finally, if the present suggestions, or some modification of them, be adopted, the two great branches of the Saxon family will realize what history shows to have been the uniform destiny of their forefathers—the carrying with them, and impressing where they tread, the characteristics of their institutions—and will be able to point out, as among their peaceful triumphs, the establishment of one weight, one measure, and one money, first for themselves, and then for all the world."

In 1857 Dr. Alexander went to Europe, charged by the National Government with a mission having in view the Unification of Coinage. His answers to the questions of the British Commission on Decimal Coinage, of which Lord Overstone was Chairman, were printed by the Commission, and form an important and perspicuous review of the whole subject. He returned without having effected any arrangements, the opposing interest of the bankers being, in his opinion, the principal obstacle to unification, or even assimilation of the coinage of the two countries. His views met with due appreciation at home, and he was about to be appointed Director of the Mint in Philadelphia, in 1867, when death prematurely put an end to his career.

Among other scientific works of Dr. Alexander's are reports made at the request of the U. S. Light-House Board, on Babbage's numerical system of light-houses, on steam-whistles as fog signals, and, in connection with the chemist, C. Morfit, on illuminating oils.

At the breaking out of the civil war, he tendered his services to the national government, and, as engineer officer on the staff of the department commander, aided in planning and constructing the defences of the city of Baltimore. He also contributed largely from his private means towards the raising and equipment of a field battery, which was commanded by his eldest son.

Dr. Alexander was not only a mathematician and a physicist, but likewise a linguist and a poet. As a linguist he could have had but few equals in this hemisphere. Latin he wrote as readily as he wrote English, with the same choice command of words and skill in construction. He was deeply versed in Greek and no mean Hebraist. The modern tongues of the civilized world were perfectly familiar to him; and he was as exact as he was varied in his gift of tongues. Among his unpublished manuscripts is a "Dictionary of the Language of the Lenni-Lenapé, or Delaware Indians," being a compilation of the several vocabularies of Zeisberger and Heckewelder, Moravian missionaries, whose activity among the Indians, chiefly in Pennsylvania, covered a long series of years. In this volume he attempts to construct etymologies, and to make intelligible the structure of that language, now entirely perished. The following is the concluding paragraph of the preface: "A similar irregularity will be found, also, in the attempt to reconcile the etymologies of various words; all of which herein rest only upon the authority of the compiler. The incompleteness, however, in this feature of the dictionary it possesses in common with, though to a greater degree than, the lexicons of accomplished scholars in other tongues. And if the meagreness and doubtfulness of this research are admitted for other languages, as well long-cultivated and classic as modern and vernacular, which count their philologers by hundreds, their words by thousands, and those who use those words by millions, something may be conceded to a dialect whose explorers are but two, and who themselves alone made it a written tongue, and of which while its genius is as potent over derivative words as the many-sided polysyllabic and mellifluous Greek, we have only remaining the scant debris, almost to be reckoned on the fingers, which the present compiler has gathered in the following pages."

The most important of Dr. Alexander's unpublished works, the titles of which are given in the appended list, is "A Dictionary of English Surnames," an announcement of which was made in the *Am. Journal of Science*, in 1860. It is a monument of learning, is thoroughly exhaustive of the subject, and bears the impress of a strong and original genius. It is to be regretted that no publisher has yet been found for it. Arrangements for its publication were interrupted by the war.

He was also a poet: not a popular poet, for there was too much depth and originality of thought and expression to secure at once the popular applause—too much purity and beauty of language, and calm quiet depth of sentiment, to win its way to the popular heart, save by slow steps. He was, however, a true poet. His Introïts and Catena are both works of a high order.

The Catena is a string of pearls, which will link his name to an immortality, in that serene region, where the sacred muse most delights to dwell, and she weaves her freshest and most beautiful garlands. The opening piece, the Prelude, and the closing piece, the Valete, are conceived in his richest vein, and marked throughout with that pathos and depth of feeling which go direct to the heart. They are exuberant in thought, musical in rhythm, profound in sentiment, and full of heart-revealing.

The above are the words of Dr. Alexander's friend who has been previously quoted. He adds: "Dr. Alexander was almost, if not quite, as deeply read in theology and church history as he was in mathematics and general literature. It is not common for a layman to push his inquiries into this region of thought; nor is it common for him to succeed, if he does. But there was nothing common in the mental calibre of our deceased friend. He prepared and published a tabular statement of the points of doctrine, in which the several systems of religious belief meet and diverge; and I hazard nothing in saying, that this remarkable exhibition of the powers of condensation and accurate discrimination would have been worthy of any prelate in Christendom. On one occasion, meeting a distinguished and most learned divine of the Lutheran faith, who did not know him, he asked for information touching some point of belief, when the gentleman replied, I know not where you will find an answer, unless it be in a sheet published by some Dr. Alexander, of Baltimore, which is the most wonderful paper that has ever met my eye."

In person Dr. Alexander was tall, finely formed, erect, and easy in motion, always neat and precise in his dress. In his intercourse with others he was so scrupulously observant of the etiquette of good breeding, as sometimes to give the impression of stiffness. A keen debater, aided by immense resources of memory, fond of argument, as an exercise of acumen, his disputations had no tinge of self-assertion, but were ever courteous and good-tempered. He liked a good intellectual tilt, and to the writer, many years his junior, it was a pleasure to engage with him, because he was sure to be gainer in facts and lore previously unknown to him. Undemonstrative in his manner to the outside world, his tender nature spent its wealth upon his family, to whom he devoted much of his time. In 1836 he married Margaret Hammer, the daughter of a prominent Baltimore merchant. She survived him, with five sons and a daughter. He was not yet fifty-five years of age when he died, cut down in the vigor of life, by an attack of pneumonia, on the 2d of March, 1867. His innate modesty and love of retirement had kept him from being called to public trusts where his admirable talents and systematic industry would have produced the most valuable results, and it is to be regretted that the public service so seldom had the benefit of the wisdom of his counsels and the assiduity of his labor. To the world of science he was well known, and here he had received the due meed of recognition. The degree of Doctor of Laws was conferred upon him by St. James College, of his native State, where he occupied the chair of Physics for a year. He occupied a similar position in the University of Pennsylvania, and subsequently in the University of Maryland. He was a member of the Maryland Historical Society, of the American Philosophical Society of Philadelphia, of the American Association for the Advancement of Science, and was one of the members of the National Academy of Science, named in the act of Incorporation.

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1849. On a new Formula for Interpolation, vol. vii, p. 14.

1849. On a new Protractor for Trisecting Angles, vol. vii, p. 243.

1849. On a new Table of the Pressure of Steam at various Temperatures, vol. vii, p. 361.

1851. On Certain Meteorological Coincidences, vol. xii, p. 1.

1853. Hassler's Experiments on the Expansion of water at various temperatures, vol. xvi, p. 170.

1854. Improved Apparatus for the Analysis of Coal, and for Organic Analysis generally. *Journ. Franklin Inst.*, 1854, p. 102.

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Greek Onomatology. 1 vol., 8vo.

A Dictionary of the Language of the Lenni-Lenapé, or Delaware Indians. 4to.

A Concordance and Analytic Index of the Book of Common Prayer. 2 vols., 8vo.

A Handy Book of Parliamentary Practice. 8vo.

The Hymns of Martin Luther, translated into English, with Notes. 8vo.

Suspiria Sanctorum. A series of Sonnets for Holy-days all th ough the year. 8vo.

Introïtus, sive Psalmi Davidici. 8vo.

Lives of the Cambists.

MEMOIR

OF

WILLIAM CHAUVENET.

1820-1870.

BY

J. H. C. COFFIN.

READ BEFORE THE NATIONAL ACADEMY, APRIL 16, 1873.

BIOGRAPHICAL MEMOIR OF WILLIAM CHAUVENET.

MR. PRESIDENT AND GENTLEMEN:

A single decade has just closed since the organization of our Academy, yet sixteen of the original fifty members have passed from us. Some of these had long been laborers and leaders in the promotion of science and scientific investigations, and all have contributed to the advancement of science and to arousing the interest of others in scientific pursuits, and have been recognized by their works and merits, as fittingly worthy of membership in our limited band.

I have now, in accordance with our rules and by your selection, to present a tribute to the memory of WILLIAM CHAUVENET, at the time of his death Vice President of the Academy. By his election to this office, you have yourselves endorsed his selection for membership; and the American Association for the Advancement of Science has added its verdict by electing him in 1869 as its president for the session of the following year. As his friends feared, when the time came, his health had become far too feeble to allow of his attendance. Years before this he had been elected into the American Philosophical Society and the American Academy of Arts and Sciences. In 1860 St. John's College, Annapolis, Maryland, one of the oldest colleges in the United States, conferred upon him the merited degree of LL.D.

His father, William Marc Chauvenet, was born in Narbonne, France, in 1790. Left an orphan while yet a boy, his education was undertaken by two older brothers, then residing in Italy, and with considerable wealth. As secretary to one of these, at the time a chief commissary in Napoleon's army in Italy, he lived in that country during a part of his youth and early manhood. There he found abundant means and time to cultivate a natural taste for music and literature. Prof. Chauvenet often remarked that his father was his severest musical critic. At the downfall of Napoleon he was forced to look elsewhere for means of support, and came first to Boston, then to New York, as a partner in a silk importing and manufacturing company. But this enterprise failed and nearly ruined him financially. Previous to this he had married Miss Mary B. Kerr, of Boston. He now gave up business. Fancying, from early association with one of his brothers, who was a somewhat noted agriculturist near Milan, that he would like a similar occupation, he purchased a farm near Milford, in Pike Co., Penn. A brief trial convincing him that he could not succeed in this enterprise, he removed to Philadelphia in 1821, engaging there in business, and this time with fair success. On the removal of the Naval School to Annapolis, in 1845, he accompanied his son, and, as that institution developed into its present form, he was appointed Assistant Professor of French. This position he held until his death, in 1855. He was endeared to those about him by a refined taste, the amenities of social life, the singular gentleness and purity of his character, and the consistency and earnestness, without obtrusiveness, of the religious faith for which he was noted. He was much esteemed and beloved, and his pupils, ofttimes very troublesome to their instructors of foreign birth, had not the heart to vex or trouble him.

To his father Prof. Chauvenet owed his love of music and literature. From his mother he appears to have inherited the logical exactness and methodical reasoning powers which are the basis of mathematical ability. She was noted for her excellent sound judgment, rarely, if ever, at fault, which, combined with tact and efficiency, and a kindly, unselfish disposition, rendered her invaluable as a neighbor and a friend. From her many estimable traits of character, she was much esteemed and beloved by those who were brought into association with her.

It was during their brief residence at Milford that their son, William Chauvenet, was born on the 24th of May, 1820. As an only child, he was carefully nurtured and cared for in Philadelphia, his home until after reaching the age of manhood. The best schools were selected for his instruction. As a boy he devoted himself but little to out-door sports, chiefly from the little opportunity afforded by a city life. But he early manifested a decided mathematical ability and a mechanical knack in his pastimes; "his kites always flew well, his fire balloons never failed." Later, "mechanical exhibitions of legerdemain would always set him at work to reason out and finally reproduce the feats he had seen performed, and almost invariably with success."

His teacher for some years previous to his entering college was Dr. Samuel Jones, then conducting what at that time was considered the best boys' school in Philadelphia. One of his pupils thus speaks of him: "In his capacity to develop his pupils' powers, in fact to educate, he certainly was a remarkable man."

Prof. Chauvenet often said that the country needed more teachers like him. It was at the earnest solicitation of this worthy gentleman, that Mr. Chauvenet, who intended his son for a line of business similar to his own, consented to send him to Yale College. His preparation in mathematical studies was not only completed, but before admission he had already mastered the whole college course in that department. At the age of fifteen he had no knowledge of Latin or Greek, yet in one year he finished his preparation in these languages, with such success that he passed readily the examinations for admission, and at the end of his first college year took the first prize for Latin composition. During his last years at college he was the only one of a class of nearly 100 who took the special optional course in mathematics.

Entering college at the age of sixteen, he graduated in 1840 with high honors, due nearly as much to his classical as to his mathematical attainments.

Afterwards, in speaking of his college life, he remarked that it was sometimes a disadvantage to a boy to be too well fitted for college, and that in his own case this led him to neglect the study, which he could always command for the use of the day at sight, so that when he graduated he felt confident he knew less of mathematics than when he entered college.

Yet in his case we need not regret the opportunity afforded for other studies. A familiarity with classical and general literature, and with the entire range of the college course, and the subsequent symmetry of his intellectual development, were valuable results.

Soon after leaving college he was selected by Prof. Bache to assist in the series of magnetic observations undertaken at Girard College in Philadelphia. The friendship here formed between them was an enduring one. In such high esteem did

Prof. Chauvenet hold this friend's judgment, that later in life he often consulted him, and was more than once guided by his advice. Many of us look back upon the friendly influence and goodly counsels of this distinguished man, imparting his own interest in scientific labors and guiding and assisting in their pursuit, as also to his continued friendship, as among the valued reminiscences of the past.

And here let me allude to another, who at that time was contributing so largely in awakening on this side of the Atlantic the interest in astronomy which resulted in the establishment of observatories, and from which have grown the many valuable observations and astronomical discussions which have given a high repute to American astronomers. At the time of which I speak, the astronomical observatory at the Philadelphia High School was established through the labors and under the direction of Mr. Sears C. Walker. To him Prof. Chauvenet, in common with others, attributed the direction of his studies to this department of science, and to the vast fund and characteristic features of German mathematical and astronomical literature.

In 1841 he was appointed a professor of mathematics in the navy, and for a few months served on board the U. S. steamer Mississippi. A brief trial so well convinced him of the uselessness, both to himself and to the midshipmen whom he was expected to instruct, of the plan of teaching on ship-board, subject to the many inconveniences and interruptions of alternate life at sea and in port, that he decided to resign his appointment.

Midshipmen were then appointed, many of them as mere boys with but little schooling; sea-life first, intellectual development afterwards, was the naval maxim then, and with some officers is even now. Five or more years at sea, with or without instructors, as the case might be, and eight months' study at a school on shore, afforded all the required preparation for examination for promotion.

The naval schools at the three principal navy yards had in 1839 been concentrated at the Naval Asylum in Philadelphia, under the charge of Professor David McClure. His death occurring in 1842, Prof. Chauvenet was appointed to succeed him, and was thus retained in the navy for the valuable services he subsequently rendered in developing the present Naval Academy from this small beginning.

Young as he was, younger than many of his pupils, he inspired them with respect, and awakened an interest in their studies, so that something more than a practical acquaintance with the rules in Bowditch's Navigator was attempted by a few better educated or abler than the rest. A course of mathematical study was arranged, and obtained the sanction of the secretary of the navy. In one of his letters, prepared for an historical account of the Naval Academy, Prof. Chauvenet speaks in some detail of the almost ludicrously insufficient appliances and accommodations of the school, adding: "I found, however, that it was only uecessary to ask for the necessary appliances to have them liberally granted."

The need of an institution for the education of officers of the navy, similar to that which had long been provided at West Point for those of the army, had, almost from the foundation of our present government, been urged on the attention of Congress and secretaries of the navy. Officers of high standing and of several grades were earnestly pleading for it, and some of the professors of mathematics had represented in strong terms the utter inefficiency of instruction at sea. But our secretaries of the navy were not all to blame for their apparent want of interest and neglect of so important a matter. The plans presented, many of them crude and imperfect, and almost as various as the individuals who offered them, could hardly be digested into a system by one in so laborious an office. With some exceptions these plans required the action of Congress. The idea that such an institution might be a growth, instead of a creation, was entertained by few.

Prof. Chauvenet did not stop with the slight advance which a limited eight months' course allowed. He drew up a plan for the expansion of the existing school into a regularly organized institution, in which all the subjects regarded as indispensable in the education of a navy officer were to be taught under competent instructors. He represented to the several successive secretaries (there were many in a few years) that they had the same power to send to the school several of the professors under their command, as only one, and other officers who might be willing to engage in instruction. "The first object was to initiate a successful course of study, and then to ask Congress to support it."

Prof. Bache entered earnestly into his views, and succeeded in awakening an interest in the matter at the Navy Department. But to place midshipmen at a naval school before going to sea was too radical a change to be at once adopted. A two years' course, subsequent to sea-service, was all that was formally sanctioned, to go into effect in October, by Secretary Henshaw, but only to be revoked by one of his successors. The precedent, however, was established, and early in 1845 these views were effectively pressed on the new secretary, Hon. George Bancroft; and, the asylum at Philadelphia being needed for the veteran seamen, for whom it was intended, the naval school was removed to Fort Severn, at Annapolis, Maryland. A board of officers entered only so far into the views of its youngest member, that a plan was adopted of two years' instruction at the school, a service at sea of two or three years, and a final course of two years at the school. But even this advance was rescinded by a new secretary within a year. The old term of eight months was restored; but with great improvement in the course, not only in mathematics, but in providing better instruction in seamanship, and gunnery, and a little mechanics.

Undiscouraged by these failures, he still persisted, but it was not until 1851 that a four years' course before sea-service was adopted, and the Naval Academy in its present form was commenced. And yet it was an imperfect development of his plans. The arithmetic of whole numbers, with reading, writing, and spelling, were, and even for several years after his leaving the Academy, the only requisities for admission, and only within the last two years have the school studies of arithmetic, English grammar, and geography, which occupied the greater part of the first year, been remitted to the preparatory schools. It fell far short of the ideal for which he had been so long laboring. This required a much higher standard of admission, a more extended course; and, beyond this, that the chief instructors should be of recognized ability and attainments in their several departments, and that the graduates should be brought back, nominally as assistant instructors, but to give them opportunities for further studies; and moreover that the Academy, by its appliances, means, and aids for professional studies, should offer inducements to graduates to resort to it for further prosecution of any of the subjects which enter into their profession. In his own department he provided for this by the erection of a small observatory, in which were an equatorial and a meridian circle by Repsold, the latter constructed much after his own plans, and manifesting in many of its arrangements the mechanical tact which had characterized him in early life. There were others who sympathized with his views and aided his efforts. But his was the guiding mind. The Naval Academy is more indebted to him than to any other for its development and organization. He availed himself of the opportunities which his position afforded, and proved to be the right man at the right time in the right place.

At first as professor of mathematics and astronomy, later of astronomy, navigation, and surveying, he was always the most prominent of the academic staff. The Academy derived reputation from his recognized ability. His sound judgment and just appreciation of all branches of instruction and all the wants of the institution gave to his opinions a controlling weight in the counsels of the academic board.

In a term of sixteen years, a large number of officers came in successive classes under his instruction. His intellectual abilities, his thorough knowledge of the subjects of instruction, the wide range of his attainments, a just appreciation of merit, an unwavering integrity, a uniform disposition, never disturbed by passionate excitement, and a kindly interest in those with whom he was associated, gained the esteem and respect of all. In naval circles his memory is revered.

In the recitation room he was noted for logical exactness, and for that peculiar tact, in which many fail, of promptly detecting what is in the mind of the student, and guiding his logical processes without being engrossed by his own.

In 1855, he was offered the professorship of mathematics in Yale College, but he was not ready then to relinquish his work at the Naval Academy; and again the professorship of astronomy and natural philosophy in 1859. This recognition by his Alma Mater was a gratifying and appreciated honor. At the same time, he was elected to the chair of mathematics in Washington University, then recently established in St. Louis by the munificence of its citizens.

Weighing well the claims of each, and considering all the circumstances of a connection with either, he decided in favor of St. Louis. It was with him mainly a choice, though there were other inducements, between an institution recognized as one of the highest, oldest, and of most repute, and one just beginning life, but organized on plans and with a liberal scope which he approved, and where conscious usefulness would be his best reward.

But he found it necessary to regard the welfare of his family. The west seemed to offer a better field for the future of his sons, from whom during their education he did not wish to be separated. His long and patient labors in introducing into the navy an education deserving of the name, except in the estimation in which he was held, had received no fitting reward. At the Naval Academy he had not the means of providing for the education of his children, who were advancing to an age requiring higher and better schools than the neighborhood afforded. The fruitlessness of repeated efforts of himself and associates (they had but little aid, and even incurred opposition, from others) left little hope for the future. He felt a strong reluctance to sever old ties and associations, and left with regret the field to which he had devoted the best portion of his life. It is to the discredit of the Naval Academy, or rather of those who controlled its interests, that he was suffered to depart without any effort to retain him. But his loss was deeply felt by all who had the best interests of the Academy at heart. A few years later, when it was restored to its old moorings, from which it had been driven at the commencement of the war, and had suffered from want of proper appliances and unfavorable circumstances of its location in Newport, and many consequent irregularities, and the process of restoration had been successfully commenced, he was solicited to return. It needed one of his reputation to restore it to its former repute. But as long as the Naval Academy exists, his memory will not be forgotten.

Entering with characteristic energy in his new field, he gained at once the confidence and high esteem of those with whom he was associated. And in 1862, on the death of Chancellor Hoyt, he was chosen Chancellor of the University. His inaugural address in the following year, on the trite subject of education, evinces a breadth of philosophic thought, and a just appreciation of all departments of inquiry in which the human mind can enter, which render it well worthy of attention. In the organizing and superintending the several schools of instruction, and in his own special department, his memory claims and receives a lasting tribute of gratitude from the friends and supporters of that important and rising institution.

Unhappily, in the spring of 1864 his health gave way, and, travelling in Wisconsin and Minnesota with hope of restoration, he was suddenly recalled to St. Louis by the death of his mother. The following winter and spring were spent in Minnesota, and he was so far restored that he was able to attend the meeting of our Academy at Northampton in August 1865, and in the fall to resume his duties at the University. The trustees had showed their appreciation of his worth by not accepting his previous resignation.

He devoted himself assiduously to his duties; but, his health again failing, he was obliged in 1869 again to relinquish them and resign his position. Passing the summer in Colorado and Minnesota, and the following winter in Philadelphia, in the spring, by the advice of his physicians, he went to Aiken, S. C. But it was too late to derive benefit from that benign climate. Returning to St. Louis, and thence to Minnesota, where he had previously been so much benefited, he finally closed a laborious, useful life at St. Paul, Minnesota, on the 13th December, 1870, in the 51st year of his age.

In developing and giving character and reputation to two distinguished educational institutions, he had done a noble work.

His professional duties were at all times arduous. At the Naval Academy, ofttimes four, and sometimes six hours a day, were required in the recitation room; yet he found time to prepare a work on trigonometry, published in 1850, which has been justly spoken of as "an important addition to our mathematical literature, being the most complete treatise on trigonometry extant in the English language.[1] While it contains everything useful to the mathematician and astronomer, the more elementary portions of the work are easily distinguished by the large type in which they are printed, and form of themselves a connected treatise, adapted to the wants of the young student." Yet it pursued the subject to its higher developments, supplying almost every want in astronomy and geodesy, and of those who required trigonometrical analysis in its varied forms as an instrument of investigation. It introduced the American stu-

[1] Journ. Frank. Inst., vol. xx., 3d series, p. 215.

dent to the methods of the German school, noted for the rigor and generalization and exhaustive character of its discussions, and to many topics wanting in all the text-books in the highest colleges in this country and in England, and found by our mathematical students only in German, French or Latin. The Gaussian equations, the finite variations and differentials of trigonometric expressions, the solution of the general spherical triangle, and the development of several functions into series of multiple angles, are instances most readily noted. What was found in many books was digested into a connected treatise, remarkable for its symmetry, its thorough exactness, and the clearness, conciseness, and purity of language of every expression. It is the only text-book in any branch, I have ever used, which I never criticized or found fault with. After the writings of Cagnoli, Gauss, Bessel, and others, it was hardly to be expected that anything new could be developed. Yet there are not a few topics which are new, and others in which he improved the discussions of these great masters.

At the time of its publication trigonometry in many of our colleges was restricted to the simple cases of plane and spherical triangles, by the trammelling geometric processes. Analytical trigonometry was but little known except to those engaged in astronomical or geodesic work. This book supplied a pressing need of the times, and, as a classic and complete work on the subject of which it treats, it will be long before it is superseded.

His manual of Spherical and Practical Astronomy was commenced at Annapolis, but completed at St. Louis, and, through the commendable liberality and appreciation of his friends in that city, published in 1863. In spherical astronomy it embraces all the topics which come up in the work of an observatory, or in astronomical work on land or at sea, and each is treated with the exhaustive generality and mathematical rigor of the German school. The whole is wrought into a symmetrical treatise, remarkable for its clearness and simplicity, and which could only be the work of a master mind, fully conversant with the subjects which it discussed. As has been aptly said by one well able to judge, "It represents astronomy in its most modern and perfected forms of research. Many of its investigations are either wholly or in part original, such, for example, as some of the formulæ for latitude and eclipses, occultations of planets, improved method of lunar distances, etc."

The second volume on Practical Astronomy evinces the same completeness and thoroughness of analysis. It discusses, in an elaborate and exhaustive manner, all the best instruments used for astronomical observations, whether in the higher observatories, or in the more modest work in the field or at sea. An appropriate chapter on the method of least squares is added, in which the subject is treated with a perspicuity, and freedom from the mystery in which it has been shrouded, found nowhere else.

Each chapter is a monograph by itself, but here treated in unison with the rest, and with a noted symmetry. The theory of each instrument is admirably discussed, with all its needful appendages. It is not a minute description of a particular instrument, with its peculiar arrangements, but of its essential parts, while, as also in the first volume, there are many valuable suggestions and examples, illustrating what is needed and what is best in practice. It may need extension, as many subsequent improvements demand, but as yet it stands far above all others in the subjects of which it treats.

It is deeply to be regretted that failing health prevented his taking up another department of practical astronomy, which relates to the orbits and perturbations of the various bodies of our solar system. But another of our associates, Prof. J. C. Walton, with the exhaustive processes of the same school, has supplied this want.[1]

It is a marked evidence of the advancing progress of science among us, that each of these works, published as a hazardous experiment and with the supposition that few copies only would be required, has met with an increasing demand from year to year. The Astronomy is called for as much abroad as here. Both works exhibit a rare combination of the able mathematician, the skilled observer, and the expert instructor, fully appreciating the wants of the student.

In his early years at Philadelphia (1843), he published a work on the theory of logarithms, far more extensive and elaborate than what is found in our college text-books. It manifests the

[1] Am. Journ. of Sci. and Arts, xxxvi., 2d Series.

same thoroughness and exactness which are conspicuous in his later writings.

Several papers, chiefly on trigonometrical and astronomical problems, appeared at various times in the scientific journals. The most noted is on lunar distances, subsequently incorporated in his Astronomy, which, while equally rigorous with that of Bessel, was adapted to the usual tables in the British and American Ephemerides, and so simply and admirably arranged, that the non-mathematical navigator could use his method with almost equal facility as the imperfect processes usually employed.

In 1854 he devised and had constructed a "great circle protractor," by which at sea the course in a great circle could be determined with almost as much ease, as on a rhumb-line by a Mercator chart; and spherical triangles could readily be solved to the nearest quarter of a degree. This drew largely on his pecuniary resources, from which, a long time after, he was only partially relieved by its purchase by the hydrographic office.

At Philadelphia, in the last winter of his life, and when physical failing might well excuse from intellectual labor, he occupied himself with completing and publishing a work on the Elements of Geometry. It would seem as though an addition to the numerous books of this class was hardly needed, and could offer nothing new. Yet, following the system of Legendre, he wrote the whole in his own clear, precise style, improving wherever improvements could be made, and occasionally introducing a new proposition or a new mode of solution, and enlarging the limits of this fundamental branch. The addition of judiciously selected problems to be solved by the pupil supplied a needed want. Excellent as are some of the books on this subject which preceded it, it is an improvement on them all. It is more that it was the closing labors of his life that I speak of it here; but let us not forget, that, next to those who are directly laboring to extend and advance science, they contribute to its progress who prepare fitting aids to the young beginner, and remove the difficulties in his way.

In his youth he had become an expert performer on the piano, and, even up to the time of his leaving college, the strongest of all his tastes was for music; and he pursued its study, with characteristic earnestness and thoroughness, with the idea of devoting himself to it as a profession. Happily he was dissuaded from this, and mathematical studies became his life work. But his love for music continued, and his enthusiasm and interest in it were marked characteristics up to the close of life. As only hours of recreation could be devoted to it, he confined himself to that which was of a classical character. Becoming acquainted with the works of Beethoven, he studied the interpretation of them with such success, that his rendering of them was always listened to in social circles with a silence which few others could command. Many declared that they never understood or appreciated these noble compositions until they heard them as rendered by him. As a musical critic, mere execution never satisfied him. It was not the artistic skill of the performer, of however high an order, but the music itself which roused his enthusiasm. In a letter not long before his death, after listening to Adelaide, a song by Beethoven, as sung to his accompaniment, he says, "It was tame as moonlight, where it should burn like a mid-day sun. I have never yet heard this song sung, except in my own soul. *Can* it be sung by the voice?" Again, after hearing a violin and piano sonata of the same great composer, he writes: "It was another revelation to me of Beethoven's many-sided nature. The Scherzo has haunted me ever since, and as I write, my pen will move only to the rhythm of it. Another played from Chopin and Mendelssohn, but everything pales before Beethoven's glorious effulgence."

In the various social circles in which he moved at different times, his society was always prized. The charm of his power of musical entertainment was fully supplemented by the wide range of subjects in which he was at home, for whatever he read, he read thoroughly and well, so that it became his own. In the more limited circle of intimate friends, his warm heart and affectionate interest, and judicious counsels, when needed, made him an invaluable associate, and there are many who have deeply deplored his loss. Charitably overlooking their faults, he constantly and unconsciously set before them an example of a life governed by elevated principle, and exhibiting a constant uniformity of disposition, never yielding to impulses and passions, and rarely if ever at fault. Such a one could have no enemies.

In his family the warmest traits of his character were constantly exhibited. In 1842, soon after taking charge of the naval school in Philadelphia, he married Miss Catherine Hemple, of that city. It was a union of affection, which continued through his life, and, according to their religious faith, is not ended yet. He was devoted to his children, even in most laborious days, finding time in their childhood to join in their sports and contribute to their amusement, and in after years to guide their reading and studies and direct their tastes. He was their companion and friend.

Besides his wife, a daughter and four sons survive him. The former inherits his musical taste and ability, one of his sons is devoting himself to chemistry, and is state chemist of Missouri; the others, still young, are promising careers of usefulness. They all have our earnest sympathy in the loss they have sustained.

With his parents, he was a reader of Swedenborg and a believer in his doctrines. But a Swedenborgian in the sense of a belief in Swedenborg as the only guide of faith, he certainly was not. He admired his writings, and found in them a breadth and extent of philosophic and scientific thought, which accorded well with his earnest character. *Nullius jurare in verba magistri* was a maxim of his life, and he brought all religious thought to the test of the written word. He never obtruded the peculiarities of his faith on those who differed from him. But, in his constant unswerving religious life, he manifested his earnest faith in the religion which he professed.

In his inaugural address, already referred to, he says: "All education must have reference to man's destiny as an immortal being. If there is no future life, if all man's future hopes and aspirations are bounded by the finite horizon of this material existence, there is nothing left us but to enjoy the greatest amount of physical and intellectual happiness possible; and the only education desirable is that which teaches us the condition and limitation of human enjoyment." "If man is immortal, the education which he receives here must be but the first step of an indefinite progress. We are not to think of him as becoming immortal *after death*, but as immortal here and now." This close linking of our life here with that hereafter, and our intimate connection with the spiritual world, characterize the school of religious thought which he had embraced. This was his firm belief, and his whole life was consistent with such elevated and elevating faith. And in this he saw nothing inconsistent with the highest development of our mathematical, physical or natural science, but that it presented a different field of thought and sentiment. Those and other teachings of the sacred Scriptures he regarded as adapted to man's spiritual nature, and necessary to his highest wants. Can we afford to ignore them, constituted as we are by our Creator? He has passed from earthly life, with firmly grounded hope and aspirations for that higher life.

I append the following list of his published works and papers :—

Binomial Theorem and Logarithms for the use of the Midshipmen at the Naval School, Philadelphia. *Philadelphia*, 1843, pp. 92.

Solution to a Case of Sailing. *Amer. Journ. Sci. and Arts*, xlvi, 1844.

On the Method of Determining the Geographical Latitude by Altitude of the Moon. *Amer. Journ. Sci. and Arts*, liii, 1849.

On Lunar Distances. *Proc. Amer. Association*, 1850.

A Treatise on Plane and Spherical Trigonometry. *Philadelphia*, 1850, pp. 256.

On Unlimited Spherical Triangles and their Solution. *Gould's Art. Journ.*, i, 1851.

On the Employment of the Theorem, "Small Angles are Proportional to their Sines." *Gould's Art. Journ.*, i, 1851.

On a New Method of Correcting Lunar Distances for Parallax and Refraction. *Gould's Art. Journ.*, ii, 1852.

Tables for Correcting Lunar Distances. *Amer. Ephemeris and Nautical Almanac*, 1855; 1852.

Improved Method of Finding the Error and Rate of a Chronometer by Equal Altitudes. *Amer. Ephemeris and Nautical Almanac*, 1856; *Proc. Amer. Association*, 1853.

Some New Formulas of Spherical Astronomy. *Gould's Art. Journ.*, iii, 1854.

Note on the Solution of some Trigonometrical Equations by Series. *Gould's Art. Journ.*, iii, 1854.

A Simple Method of Correcting the Common Nautical Method of Double Altitudes of the Sun, Moon, or a Planet for the Change of Declination between the Observations. *Proc. Amer. Association*, 1856.

On a Method of Determining the Latitude of a Place from the Observed Times, when two known Stars arrive at the same Altitude. *Proc. Amer. Association*, 1856.

On the Method of Finding the Longitude of a Place by Transits of the Moon and a Star over the same Vertical Circle. *Gould's Art. Journ.*, v, 1858.

Note on the Projection of a Great Circle of a Globe on a Mercator Chart. *Math. Monthly*, i, Cambridge, 1860.

On the Locus of Perpendicular Tangents to any Conic Section. *Math. Monthly*, ii, Cambridge, 1860.

A Manual of Spherical and Practical Astronomy, vol. i, Spherical Astronomy, pp. 708; vol. ii, Theory and Use of Astronomical Instruments. Method of Least Squares, pp. 632. *Philadelphia*, 1863.

A Treatise on Elementary Geometry, with Appendices containing a Collection of Exercises for Students and an Introduction to Modern Geometry, pp. 368. *Philadelphia*, 1870.

MEMOIR

OF

JOHN FRIES FRAZER.

1812—1872.

BY

JOHN L. LE CONTE.

READ BEFORE THE NATIONAL ACADEMY, OCT. 22, 1873.

BIOGRAPHICAL MEMOIR OF JOHN F. FRAZER.

In accordance with the wish of the Society, expressed at the meeting of October 18, 1872, I have prepared the following brief memoir of John F. Frazer, LL.D., Professor of Natural Philosophy and Chemistry in the University, and who held successively the offices of Secretary and Vice-President in this Society: a man of eminent scientific and general culture; of singular truthfulness of speech, and integrity of conduct; a devoted lover of consistency in action, and strict performance of duty; virtues which he exemplified in himself and sought for in others.

He was therefore respected by his acquaintances, and beloved by his friends, with whom he interchanged a strong and unselfish affection; one who will live in the memory of those admitted to his intimacy, as of those who have had the good fortune to sit under his instruction.

John Fries Frazer was born in Philadelphia, July 8, 1812, in Chestnut Street, nearly opposite Independence Hall. His father was Robert Frazer, a brilliant and successful lawyer of that time. who married Elizabeth, daughter of John Fries.

He was grandson of Lieut. Col. Persifor Frazer, an active officer in the Revolutionary War.

During his childhood, being placed at school in Philadelphia, he was always among the leaders of his classmates, both in the serious pursuits of the hours of instruction, and in the athletic sports of the recesses. After a year spent, about 1822, at the quasi-military school of Capt. Partridge, in Connecticut, he completed his boyish education under Dr. Wylie, and entered as a student in the University of Pennsylvania.

His acute powers of observation, and the indications of true and manly qualities soon attracted the notice of Prof. A. D. Bache, under whose instruction he now came, and whose influence tended to the development of those scientific tastes, which eventually became the foundation of his continuous work in life. The relations thus established between professor and pupil, resulted, as is rare in the United States, in a tender and permanent affection, which will be referred to at greater length hereafter.

While acquiring his scholastic education, he had the benefit of the most thorough old-time training, which could be obtained in the family of the Rev. S. B. Wylie, D.D., "and in company with his sons, he had been drilled in the classics and mathematics, in a style unknown to these degenerate and superficial days."[1]

During his boyhood and adolescence, he was chiefly under the care of his maternal grandfather, John Fries, and afterwards under the general care of Charles Roberts, the father of our fellow-member S. W. Roberts, and of his brother-in-law, the late John Rhea Barton, M.D.

While passing through the academic course of the University of Pennsylvania, and for some time after graduation, he acted as the laboratory assistant of Prof. A. D. Bache; and in this function he aided in determining "with accuracy, for the first time in this country, the periods of the daily variations of the magnetic needle,"[2] and the connection of the aurora borealis with magnetic forces.

An additional training in physical and natural science was obtained while he held the position of assistant in the Geological Survey of Pennsylvania, under Prof. H. D. Rogers, in 1836.

About this time he perfected his youthful education by a course of law, in the office of John M. Scott, at the end of which he was admitted to practice.

The practice of his profession soon became less attractive than the more laborious, though less remunerative intellectual pursuits, which he had cultivated under the instruction of Prof. Bache. For some time he was Professor in the High School of Philadelphia, when the Professorship of Chemistry and Physics in the University becoming vacant by the resignation of Prof. Bache, Mr. Frazer was chosen to fill the chair. He was then the youngest member of the faculty, and continued to hold the posi-

[1] Penn Monthly, Nov. 1872, p. 630.

[2] Eulogy of Prof. A. D. Bache, by Prof. Joseph Henry. Report of Smithsonian Institution, 1870, p. 7.

tion until his death, when he was the senior Professor, and had been for many years Vice-Provost.

He now devoted himself most industriously to filling the duties of his professorship, and its collateral occupations, among which were many courses of lectures on various branches of physical and chemical science at the Franklin Institute, and the editorship of its Journal, from the year 1850 to 1866; the pages of which, during those seventeen years, bear evidence of his extensive reading and judicious selection from contemporaneous scientific journals of both continents.

He was elected a member of the American Philosophical Society in 1842, and was soon honored with an official position, being made Secretary in 1845, and Vice-President in 1855. He remained in office until the end of 1858, when owing to some unhappy differences which then distracted the Society, he resigned. He was re-elected in 1867, and was afterwards frequent in his attendance at the meetings, taking part in the discussions which occurred on matters of science and business.

He was one of the fifty original members of the National Academy of Sciences, chartered in 1863 by the Government of the United States: an institution intended to represent the highest scientific culture of the country. The members are pledged to make reports, without compensation, on all subjects of science, on which the opinion of the Academy is required by the Government. After remaining an active member for several years, and serving upon committees, he retired to the grade of honorary member, to make room, as he said, for some more energetic investigator, better entitled to the place.

The labor of teaching such comprehensive branches of science as Physics and Chemistry, became greatly increased by the rapid developments of modern research, and at length the symptoms of over-fatigue manifested themselves. An obscure affection of the liver had afflicted him for several years, causing frequent and constantly increasing fits of fainting, accompanied with great bodily prostration. In 1856 he was ordered by his physician to seek, in a four months' trip to Europe, a relief which his family and best friends hardly dared to hope would be afforded him. The effect of this brief relaxation was marvellous: not only was he enabled to resume his duties the following autumn with renewed vigor, but the fainting fits did not recur, except in one or two isolated instances, and the development of the hepatic disease seemed to be permanently arrested. Other and equally serious affections resulted from the excessive work to which he again applied himself during the next eleven years, so that another trip to Europe was advised in 1867. This time, sixteen months' rest from the labor of teaching and freedom from anxiety so far restored his health, that on his return, in the autumn of 1868, he was again able to resume the full duties of his chair.

These he continued, without intermission, other than that afforded by the usual vacations, until October 12, 1872, the day following the inauguration of the new University Building, in West Philadelphia. He had taken great interest in this improvement of the institution to which he had given the best labor of his life, and had patiently looked forward to it for opportunities of larger usefulness.

Never, as I have been told by those that saw him on that and the preceding day, had he appeared in better spirits, never more cheerful, although the unusual labor connected with the organization of his departments, and the transfer of the apparatus, with his large scientific library to the shelves in the new building, had entirely exhausted him.

Without premonition of cardiac trouble, which, indeed, though suspected, had never given him any serious inconvenience, and was disregarded in consequence of the graver hepatic disease above mentioned, Prof. Frazer, although much fatigued by the ceremonies of the inauguration of the previous day, went to his laboratory, and having ascended a flight of stairs leading to the apparatus room, dropped suddenly from exhaustion of the heart. Death was instantaneous and although assistance was quickly rendered, all attempts to restore life failed.[1]

Having thus mentioned the more prominent events in the public life of our deceased associate, it becomes my more difficult and delicate duty to give an analysis of his character, and to exhibit,

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[1] By a melancholy coincidence, this sad event took place on the very day on which the writer of this memoir returned after a three years' absence, in the expectation of renewing the warm and long friendship which had thus been interrupted. It was a painful greeting on arriving at home, instead of receiving the hearty grasp of affection, to see the dismal badge of woe on the residence of this valued friend.

in however an imperfect manner, the development of the life of usefulness so abruptly terminated.

The graceful tributes to the memory of Prof. Frazer by those who were closely associated with him in his professorial labors,[1] leave but little to be added by the pen of one far behind them in scholarly practice and elegance of diction, though yielding to none in his affection for our lamented friend.

Possessed of great animal spirits, with the usual concomitant of restless activity, and inheriting from his grandfather an ample competence, even the great moral power latent in his brain, at the completion of his professional education, might have served for less useful purposes, had it not been for his fortunate attachment to Miss Charlotte Cave, daughter of Thomas Cave, to whom he was married in 1838, at the beginning of his scientific career as a professor. A union which continued during his life, with singular devotion and affection on both sides, and with an influence for good over each, which may be seen but rarely even in the most happily concurrent dispositions. Two daughters and a son are the issue of this marriage, of whom the last has recently been appointed to the chair of Chemistry, resulting from a division of the functions left vacant by the death of his father.

Next in importance to the domestic influence by which he was thus controlled, must be mentioned a very potent encouragement resulting from friendship.

Prof. Frazer combined to a rare extent, correct æsthetic perception with high intelligence, ease in acquiring knowledge, retentive memory, great industry during the hours of labor, and a strict sense of moral responsibility. These elements of a powerful, useful, and conscientious mind, early attracted the notice of Prof. A. D. Bache, the master spirit of American science in those and later days. Under the genial influences of this interest, the somewhat untamed vital energies of youth were directed to the steady and laborious scientific pursuits of adult age.

It was the happy faculty of our great leader, Prof. Bache, to bind to him by most affectionate ties many of those who had been under his instruction, and it is not surprising that the regard for

[1] Vide Penn Monthly, Nov. 1872, p. 629, for a touching editorial; ibid., Dec. 1872, p. 728, for full reports of the eloquent remarks at the faculty meeting of the University by Professors Allen, Krauth, Lesley, and Jackson.

the tutor and professor of his youth ripened in the soul of Prof. Frazer into reverence and affection for the friend of his mature life.

Thus protected by love, friendship, and a strong sense of duty, he commenced the labor of life, and soon acquired by industry and intelligent facility of communication, power as a teacher in physical and chemical science which has been rarely equalled, and never excelled in Philadelphia. "His mind was quick in its action, and penetration beyond example. No man ever mastered a subject more rapidly, or could explain it more clearly or gracefully to others."[1] "He introduced a thousand anecdotes into his lectures, not only for the purpose of keeping the attention of his scholars awake to the subjects in hand, but to imbue their imaginations with that perfect fairness of judgment and complete collation of the knowledge of men of the past with that of men of the present, by which alone a philosophical character of mind can be formed. This made him a distinguished teacher, and won the confidence as well as excited the admiration of students."[2]

As lecturer at the Franklin Institute he was equally fortunate in the lower, though perhaps nearly as useful sphere of popularizing the different departments of physical science, and rendering them comprehensible to persons who had not the preliminary academic training of college students.

During years of laborious teaching he found opportunity to accumulate, and leisure to read (in addition to his special library of 2500 volumes), a large miscellaneous library, which filled one of the most extensive rooms in his house; and I may freely say that I have known few men who could recall, when occasion required, the material derived from such varied and extensive reading. To him could not be applied the ancient and frequently correct text, "Some there are who possess books, and others that understand them,"[3] and on many occasions, when enjoying, with other students of science, a discussion on some obscure point of ancient lore, scientific, religious, historical, or metaphysical, it mattered not which, I have been amazed with the readiness with which he would define the vague impressions of our somewhat

[1] Allen, Penn Monthly, l. c. sup. 678.

[2] Lesley, Penn Monthly, l. c. sup. p. 681.

[3] Mahabharata, Book I, Section 1 (Annals of Oriental Literature, i, p. 69).

treacherous memories, by turning to the exact page of works rarely referred to, and give us the precise information desired.

He could most happily combine the severe labors of academic teaching with industrious study, and with entire relaxation in the hours taken for social or domestic enjoyment, a power rarely found here, though not unfrequent in older communities.

It was by this happy union of qualities that he was enabled not only to keep himself well informed in the progress of nearly every branch of science, but also to retain the results of the classical instruction he received in his youth from Dr. Wylie.

Quickness of thought, great power of conversation, courtliness of bearing towards women, and brilliancy of wit, made him a most attractive member of society; while the genial manner in which his house was open to his friends on one evening of the week, brought around him a circle of laborers in intellectual pursuits. It was seldom that men of science from other States or countries visited Philadelphia without having a welcome in those weekly gatherings, giving and receiving instruction and sympathy in their respective investigations.

While the country suffered from the unhappy struggle which so nearly produced either its disruption or its entire destruction, Prof. Frazer's adherence to the cause of the Government was most strenuous. Though age and ill-health combined to deprive him of the privilege of active military service, he was among the warmest supporters of the military measures rendered necessary by the colossal proportions of the war. He was one of the early members of the Union League—at that time a most valuable and unpartisan agent in giving national effect to local patriotism.

On religious subjects the information of Prof. Frazer was almost as extensive as on those which engrossed his daily attention. Under Dr. Wylie he had read a moderately complete course of theology, and was as familiar with the books of the Bible, biblical commentaries, and ecclesiastical history as with any other part of his library.

While thus thoroughly acquainted with the varieties of theological opinion which divide the various sects composing the Christian Church, he was, with the modesty inherent in many men of thoughtful mind and earnest intellectual work, not disposed to obtrude his own personal views, or to take part in any argument in favor of the excellence of one sectarian formula over another.

It is also true that his predilection for the Society of Friends rendered him indifferent to the doctrines and human contrivances by which religious bodies are differentiated, under the gradually increasing influence of higher truth upon social evolution. But this very fact only made him more sensitive to the great principles of conduct and feeling which nominally underlie the various religious structures of modern civilization, and to the necessity of practising in himself and exacting from others an intelligent and consistent recognition of these bases of all vitality of the soul. Judged by the standard of conduct, which is the evidence of inward spiritual light, Prof. Frazer was as eminent for his moral as for his intellectual qualities.

The effects of hepatic disease upon the manifestations of moral qualities are well known to every medical man, and it is not singular that despondent feelings, accompanied with great suffering, occasionally overcame his unusually buoyant nature, and produced at times a quickness of manner and a petulance of language which doubtless gave offence to persons who were but slightly acquainted with him, and caused him to be occasionally harshly judged. But those of us who knew him closely, knew also that these were but the momentary effects of pain in a highly susceptible and active organization, which he endeavored to control, though naturally without constant success.

In his charities he was liberal and unobtrusive; ever ready to relieve distress according to his ability; always willing to work for the interests of even an indifferent acquaintance, when something useful or commendable was to be effected. His maxim was, never to neglect what seemed to be the duty of the moment—not to put off the occasion of usefulness that it might recur at a later period. It was a favorite illustration from physical science with Prof. Frazer, that much of the wrong done in the world was not intentional, but occurred from inattention to *moral parallax*—that is, by not recognizing the relative importance, subordination, and temporary variations of the manifold duties devolved upon each member of the human family.

"He was a fanatic for truthfulness and fair dealing in science and in everything else, and could not comprehend or make the least allowance for circumstances that threatened to compromise right and wrong. Perfectly fearless himself, and worshipping pluck and courage as the chief human virtues, he gave no quarter to the very shadow of equivocation or unfairness, no matter whom it concerned."[1]

It should also be observed, that although Prof. Frazer, judging by the history of former systems of thought, was not inclined to adopt as final truth what may prove to be merely scholastic teaching or glosses upon mediæval tradition, he was equally indisposed to cast aside the foundations of thought, resting upon time-honored belief and long experience, in favor of new systems of philosophy, in which the last half century has been so fertile. He required, before a proposition should be received, before it should be allowed to take the place of what preceded, that the facts upon which it was supposed to rest should be well established. A mere hypothesis, however specious, however ingenious, however pleasing to the vanity of human intellect, by explaining to humblest comprehension things not yet within the scope of our highest investigations (though perhaps quite so in the not very remote future), could never with him take the place of actual science.

To superstition on the one side, to rash and ambitious generalization on the other, as to all pretensions and shams of whatsoever nature—scientific, social, political, financial, or religious—he was a most severe enemy; and it was these things, or rather semblances of things—the spectres which afflict and deform our relations with others—that drew out the bitter denunciations which I have alluded to above as being intensified by the pains of disease, though having a natural origin in the honesty of his nature.

On the other hand, I have never heard from him, even in moments of severe suffering, anything that was intended, and very rarely anything that could be construed as personal. His criticisms, like those of the highest and best examples of conduct, were aimed at classes or groups of persons, looking rather for improvement in motive of action than to punishment for individual offence.

On the Monday after his death, Oct. 14, 1872, the Faculties of Arts and Sciences of the University met to do honor to his memory. Eloquent addresses were made by several of his col-

[1] Lesley, l. c. sup. p. 81.

leagues, and a series of resolutions were adopted, expressing the severe loss, both to the institution and the community, in the death of Prof. Frazer. Similar action was taken by the Society of the Alumni, and on the next day the body was followed to the grave by an unusually large and respectable assemblage.

Thus has passed from us one of the most highly educated men with whom it has been our privilege to associate—a sad loss to us, and equally so to the community in which, and for which, he labored with his vast accumulations of knowledge. Without ambition or vain-glory, he was content to give his whole attention to the somewhat monotonous routine of immediate duties in the city, and to be known in the greater world only to those with whom congenial dispositions, similar pursuits, or the accidents of travel had associated him; a combination of modesty, intellect, and conscience rarely to be seen. That those who come after us may find in their time an example of equal merit in these qualities, is the fervent wish of all who mourn his lost friendship.

Note.—The above memoir was originally prepared for the American Philosophical Society, and read before that body on April 4, 1873.

MEMOIR

OF

JAMES HENRY COFFIN.

1806–1873.

BY

A. GUYOT.

READ BEFORE THE NATIONAL ACADEMY, APRIL 24, 1874.

BIOGRAPHICAL MEMOIR OF JAMES H. COFFIN.

MR. PRESIDENT AND GENTLEMEN:—

AMONG the sad losses which science and the National Academy have sustained during the year just elapsed, we have to record with deep regret that of our esteemed colleague, JAMES HENRY COFFIN, LL.D., late Prof. of Mathematics and Astronomy in Lafayette College, at Easton, Pennsylvania. His untimely departure is the more to be deplored by us, because he was, at the time of his death, engaged in summing up the results of long years of patient study in a department of scientific inquiry which has, as yet, few representatives among our members.

Professor Coffin was born in Williamsburg, near Northampton, Mass., on the 6th of September, 1806, and died on the 6th of February, 1873. He was a descendant, in the fifth line, of Tristram Coffin, the first owner of the Island of Nantucket, who traced his ancestry to Sir Richard Coffin, Knight, one of the companions of William the Conqueror of England, in 1066. He thus belonged to that hardy, persevering, and intelligent race of New England pioneers, who have done so much to mould the character, and advance the civilization of the American nation.

The sterling and efficient qualities of his race were exemplified by Prof. Coffin throughout his laborious life. Left an orphan, he was educated by his uncle, the Rev. Moses Hallock, and graduated at Amherst College in 1828. Soon after, however, he made for himself an independent career by teaching, and founded, at Greenfield, Mass., one of the first and most successful manual labor schools in the country, on the Fellenberg system. Having left Greenfield in 1836, he took charge of the Ogdensburg, New York, Academy. There, while Principal of this Institution, he began, in the field of Meteorology, that regular series of investigations which he pursued, with characteristic devotion and perseverance, to the end of his life. In 1839 he became a member of the Faculty of Williams College, and in 1846 was called to the chair of Mathematics and Astronomy in Lafayette College, which he filled to the time of his death. Twenty-seven years of untiring labor, carried on in a truly self-sacrificing spirit, amidst circumstances which might have discouraged a less noble nature; his great success as a teacher; his quiet, but never flagging, enthusiasm, and the beneficent influence he exerted on his pupils, made him one of the main pillars of that institution during a long period of great depression. He lived, however, to see Lafayette College rise to the honorable position she now occupies among the American seminaries of learning.

Professor Coffin was a member of the American Association for the Advancement of Science, and was chosen a member of the National Academy of Sciences soon after its foundation. He was a constant contributor of valuable papers to both these scientific bodies.

In the department of mathematics and astronomy our lamented colleague contributed works on "Analytical Geometry," on "Conic Sections," and on the mode of calculating lunar eclipses, all of which have rendered valuable services to education. But it is in the field of meteorology that he showed himself an original investigator and the discoverer of new truths. Meteorology began to engage his attention almost as early as his college days, but his systematic investigations date from the year 1836. The element of atmospheric temperature and the laws of its daily, monthly, and annual variations had been tolerably studied. He now turned his attention to the much neglected and difficult subject of the winds, studying their course, direction, velocity, and force in connection with the variations of the barometer, the temperature, and the fall of rain. He soon found, however, that the ordinary observations with the wind vane were insufficient for his purpose. Not having at his disposal the instrument he wanted, like all original observers, he devised and manufactured one himself. The result was a self-registering anemometer, giving the direction and duration of winds for every quarter of an hour. This instrument was described by him in a paper read in 1849 before the American Association for the Advancement of Science, at its meeting in Cambridge. It was used by him at Williams College, and on the summit of Greylock, 3500 feet above sea-level; also at Lafayette College for many years, and was found so convenient, that Prof. Coffin was requested to furnish an improved duplicate of it to the new observatory constructed at Cordova, in the Argentine Republic, under the superintendence of the astronomer, our colleague, Dr. B. A. Gould.

But the requirements of meteorology are peculiar. However large and accurate the number of observations at one place may be, they are insufficient to solve the problem in question. In other departments of physical science co-operation may be only desiderable; in the study of the atmosphere, whose movements are so wide and so extensive as to embrace almost the globe in their simultaneous action, co-operation is indispensable. During more than thirty years Prof. Coffin was engaged in collecting from all quarters, either in printed documents, or by an extensive correspondence, the data necessary to determine the mean direction of the surface winds in all parts of the Northern Hemisphere, their rate of progress, their relative velocity when blowing from different points of the compass, and the modifications they undergo in all these respects in the various seasons of the year. He succeeded in obtaining data from over 600 stations on land, and numerous observations at sea, extending from the equator to 83° of north latitude, and representing in the aggregate over 2800 years. All these series were submitted to close computations, implying an amount of work of which only those who have tried it can form an adequate idea. The results of these laborious investigations were first announced by Prof. Coffin in a preliminary paper read in 1848, at a meeting of the Association for the Advancement of Science, in Philadelphia, but were more fully developed in his work on the "Winds of the Northern Hemisphere," published in the Smithsonian Contributions to Knowledge in 1852. In this work are given, in over 150 pages of tables, the results of his computations, together with his deductions from these data, illustrated by charts and numerous diagrams.

His conclusions are of great scientific importance. It had been observed before, in a general way, that the prevailing direction of the winds, in the middle latitudes, was from the west and southwest, both in the United States and in Europe; but to Prof. Coffin belongs the merit of having first established that fact on a broad and solid foundation, by a careful discussion of the extensive array of observations which he has collected. He was the first again to demonstrate the prevalence of north and northeasterly winds beyond the Arctic circle. He thus distinguishes in the Northern Hemisphere three great zones of winds. 1st. The region of the easterly or trade-winds, the northern limit of which passes in America through the parallel of 32° of latitude and thence along a slanting line to that of 42° in Europe. 2d. Further north, the region of the westerly winds, the belt of the return-trades which in America terminates with 56°, and in Europe and Asia with 66° north latitude, having thus an average width of 24°. 3d. The Polar belt with prevailing north and northeasterly winds, situated mostly within the Arctic circle. The pole of these three zones, which Prof. Coffin calls the meteorological pole, does not coincide with the geographical pole, but is situated about in latitude 84° north, and longitude 105° west of Greenwich.

It is obvious, however, that the slanting direction of the middle zone follows closely the course of the isothermal lines, and is doubtless due to the general causes which increase the temperature of the continent of Europe beyond the average due to its latitude. The views presented by Prof. Coffin on the general circulation of the winds in the Northern Hemisphere, in explanation of these three zones of wind, are in close accordance with the theoretical views which have been derived from the combined action of the difference of temperature between the polar and equatorial regions, and of the earth's rotation.

No doubt the last word has not yet been said about the circulation of the general currents of the atmosphere. The movements of the upper currents have to be better ascertained. Numerous barometric observations, especially on the limits of the zone above defined, have to teach us where accumulations or deficiencies exist in the mass of the atmosphere, before we can fully understand the everlasting circuits of the winds. The mighty influence of the continental masses, according to their extent, their individual geographical forms and their relative situation, has to be studied more closely before we can fully understand the highways and currents by which the exchange of polar and equatorial air actually takes place. But Prof. Coffin has furnished a new base for further investigations and progress in this complex science of the most unmanageable of the terrestrial elements.

His tables and maps show also plainly the modifications caused by the seasons in the course of the general winds. The monsoon winds, due to the difference of temperature of the continents and oceans, which varies with the power of the insolation, can be followed with ease both in America and Europe.

No one was more aware than himself that a larger number of facts, observed at stations more widely and uniformly spread, were needed to give a still broader foundation for the laws he had established and to perfect their expression. He did not consider his work finished by the publication of his first essay. For a score of years he continued to gather, with increased ardor, all the information to which he could have access. With this end in view, he accepted the immense labor entrusted to him by our venerable President, the Secretary of the Smithsonian Institution, of reducing and discussing the observations collected by over 800 observers, under the Smithsonian Meteorological System, and those furnished by the army from 1854 to 1859. This work was performed with his usual skill and faithfulness, and with a disinterestedness only too rare, and the results were published in a large quarto volume of over 1200 pages. All the material contained in the transactions of scientific societies of the Old World were placed at his disposal by the Secretary of the Smithsonian Institution, and diligently made use of by him. He was thus enabled to extend his investigations to the winds of the whole globe, and he read a first paper on the Wind System of the Southern Hemisphere before the American Association for the Advancement of Science in 1859. Before the same society he also read, as early as 1853, a valuable paper on "An Investigation of the Storm Curve," deduced from the relation existing between the direction of the wind and the rise and fall of the barometer." A subject which he was preparing to treat more fully before the Academy, at the time of his death.

But when our lamented colleague was ready to sum up the last results to which he had arrived, he was, in the Providence of God, called away from the scene of his earthly labors. His work, however, being in a sufficient state of forwardness to be completed by his assistants and other aid, it is hoped that it will soon be published under the auspices of the Smithsonian Institution.

The value of Prof. Coffin's investigations could not fail to be recognized. His work won for him at home and abroad, especially in England and in Germany, the well-deserved fame of a careful and reliable meteorologist, and of a discoverer of new truths in his favorite branch of study.

I have only spoken thus far of the man of mind, of the successful investigator of nature. This was the theme that I had to treat before you. This, however, is but one part, and not the most exalted of the noble character of our departed colleague. Intelligence, that powerful instrument for acquiring knowledge; for reading God's wisdom in the great book of the universe, is not *all* of man. His deeper nature aspires higher than this finite world revealed to us by the senses, and the measure of his moral excellence is given by the degree of intimacy he holds with the heavenly Source of all perfection.

Permit me, therefore, to add a few words on Prof. Coffin's moral nature, on those qualities of character, which, in all men, constitute the real individual, whom we love or hate, esteem or despise. This task, indeed, is a pleasant one, for it does the soul good to contemplate such an assemblage of genuine virtues as we find in our friend and late fellow laborer.

Naturally modest, unobtrusive, and absolutely unselfish, he never sought to impose himself or his opinions on others. His kindness of heart, his gentleness, coupled with great firmness, energy, and perseverance, exerted, however, a strong and beneficent influence on his surroundings. His profound love of truth made him the cautious, candid, and persevering observer whom we know, while his inquiring mind kept his eye open to every ray of light, from whatever quarter it might come. He was conscientious to a fault in the performance of even the most trifling duties. The same upright honesty which guided him in his scientific inquiries, he also applied to the earnest research for the solid foundation of his religious life.

At an early age he passed through that ordeal of self-examination, which prepares our deliberate and conscious acceptance of the truths taught us during our younger days, and soon sailed from the troubled waters of uncertainty into the harbor of peace, where he found rest and joy.

The blessed consequences were apparent in his moral purity, his sincere love for his fellow-men, which won him the esteem and love of all. His devout spirit and consistent Christian life secured for him a still higher reward: the approbation of the Father and Master of us all, whom he so sincerely loved, and so faithfully tried to serve.

MEMOIR

OF

JOHN TORREY.

1796-1873.

BY

ASA GRAY.

READ BEFORE THE NATIONAL ACADEMY, APRIL 15, 1873.

BIOGRAPHICAL MEMOIR OF JOHN TORREY.

JOHN TORREY, M.D., LL.D., died at New York, on the 10th of March, 1873, in the 77th year of his age. He has long been the chief of American botanists, and was at his death the oldest, with the exception of the venerable Ex-President of the American Academy (Dr. Bigelow), who entered the botanical field several years earlier, but left it to gather the highest honors and more lucrative rewards of the medical profession, about the time when Dr. Torrey determined to devote his life to scientific pursuits.

The latter was of an old New England stock, being, it is thought, a descendant of William Torrey, who emigrated from Combe St. Nicholas, near Chard, in Somersetshire, and settled at Weymouth, Massachusetts, about the year 1640.[1]

His grandfather, John Torrey, with his son William, removed from Boston to Montreal at the time of the enforcement of the "Boston Port Bill." But neither of them was disposed to be a

[1] In some notes furnished by a member of the family, the descent is endeavored to be traced through the eldest of the five sons who survived their parent, namely, Samuel, who came with him from England, became a minister of the gospel, and had the unprecedented honor of preaching three election sermons (in 1674, 1683, and 1695), as well as of having three times declined the presidency of Harvard College (after Hoar, after Oakes, and after Rogers). Although educated at the College, he was not a graduate, because he left it in 1650, after three years' residence, just when the term for the A.B. degree was lengthened to four years. The tradition has it, that, "at the prayer-meetings of the students, he was generally invited to make the concluding prayer,"—for which an obvious reason suggests itself,—for, "such was his devotion of spirit that, after praying for two hours, the regret was that he did not continue longer." Students of the present day are probably less exacting.

The desire to claim a descent through so eminent a member of the family is natural. But our late venerable associate, Mr. Savage, in his Dictionary of early New England families, states that he could not ascertain that Samuel had any children.

refugee. For the son, then a lad of seventeen years, ran away from Canada to New York, joined his uncle, Joseph Torrey, a major of one of the two light infantry regiments of regulars (called Congress's own) which were raised in that city; was made an ensign, and was in the rear-guard of his regiment on the retreat to White Plains; served in it throughout the war with honor, and until at the close he re-entered the city upon "Evacuation Day," when he retired with the rank of captain. Moreover, the father soon followed the son, and became quartermaster of the regiment. Captain Torrey, in 1791, married Margaret Nichols, of New York.

The subject of this biographical notice was the second of the issue of this marriage, and the oldest child who survived to manhood. He was born in New York, on the 15th of August, 1796. He received such education only as the public schools of his native city then afforded, and was also sent for a year to a school in Boston. When he was fifteen or sixteen years old his father was appointed Fiscal Agent of the State Prison at Greenwich, then a suburban village, to which the family removed.

At this early age he chanced to attract the attention of Amos Eaton, who soon afterwards became a well-known pioneer of natural science, and with whom it may be said that popular instruction in natural history in this country began. He taught young Torrey the structure of flowers and the rudiments of botany, and thus awakened a taste and kindled a zeal which were extinguished only with his pupil's life. This fondness soon extended to mineralogy and chemistry, and probably determined the choice of a profession. In the year 1815, Torrey began the study of medicine in the office of the eminent Dr. Wright Post, and in the College of Physicians and Surgeons, in which the then famous Dr. Mitchill and Dr. Hosack were professors of scientific repute; he took his medical degree in 1818; opened an office in his native city, and engaged in the practice of medicine with moderate success, turning the while his abundant leisure to scientific pursuits, especially to botany. In 1817, while yet a medical student, he reported to the Lyceum of Natural History—of which he was one of the founders—his Catalogue of the Plants growing spontaneously within thirty miles of the city of New York, which was published two years later; and he was already, or very soon after, in correspondence with Kurt Sprengel and Sir James Edward Smith abroad, as well as with Elliott, Nuttall, Schweinitz, and other American botanists. Two mineralogical articles were contributed by him to the very first volume of the American Journal of Science and Arts (1818–1819), and several others appeared a few years later, in this and in other journals.

Elliott's sketch of the Botany of South Carolina and Georgia was at this time in course of publication, and Dr. Torrey planned a counterpart systematic work upon the botany of the Northern States. The result of this was his "Flora of the Northern and Middle Sections of the United States, *i. e.*, north of Virginia;" which was issued in parts, and the first volume concluded in the summer of 1824. In this work Dr. Torrey first developed his remarkable aptitude for descriptive botany, and for the kind of investigation and discrimination, the tact and acumen, which it calls for. Only those few—now, alas, very few—surviving botanists who used this book through the following years can at all appreciate its value and influence. It was the fruit of those few but precious years which, seasoned with pecuniary privation, are in this country not rarely vouchsafed to an investigator, in which to prove his quality before he is haply overwhelmed with professional or professorial labors and duties.

In 1824, the year in which the first volume (or nearly half) of his Flora was published, he married Miss Eliza Robinson Shaw, of New York, and was established at West Point, having been chosen Professor of Chemistry, Mineralogy, and Geology in the United States Military Academy. Three years later he exchanged this chair for that of Chemistry and Botany (practically that of Chemistry only, for Botany had already been allowed to fall out of the medical curriculum in this country) in the College of Physicians and Surgeons, New York, then in Barclay Street. The Flora of the Northern States was never carried further; although a "Compendium," a pocket volume for the field, containing brief characters of the species which were to have been described in the second volume, along with an abridgment of the contents of the first, was issued in 1826. Moreover, long before Dr. Torrey could find time to go on with the work, he foresaw that the natural system was not much longer to remain, here and in England, an esoteric doctrine, confined to profound botanists, but was destined to come into general use and to change the character of botanical instruction. He was himself the first to apply it in this country in any considerable publication.

The opportunity for this, and for extending his investigations to the Great Plains and the Rocky Mountains on their western boundary, was furnished by the collections placed in Dr. Torrey's hands by Dr. Edwin James, the botanist of Major Long's expedition in 1820. This expedition skirted the Rocky Mountains belonging to what is now called Colorado Territory, where Dr. James, first and alone, reached the charming alpine vegetation, scaling one of the very highest summits, which from that time and for many years afterward was appropriately named James's Peak; although it is now called Pike's Peak, in honor of General Pike, who long before had probably seen, but had not reached it.

As early as the year 1823, Dr. Torrey communicated to the Lyceum of Natural History descriptions of some new species of James's collection, and in 1826 an extended account of all the plants collected, arranged under their natural orders. This is the earliest treatise of the sort in this country, arranged upon the natural system; and with it begins the history of the botany of the Rocky Mountains, if we except a few plants collected early in the century by Lewis and Clark, where they crossed them many degrees further north, and which are recorded in Pursh's Flora. The next step in the direction he was aiming was made in the year 1831, when he superintended an American reprint of the first edition of Lindley's Introduction to the Natural System of Botany, and appended a catalogue of the North American genera arranged according to it.

Dr. Torrey took an early and prominent part in the investigation of the United States species of the vast genus *Carex*, which has ever since been a favorite study in this country. His friend, Von Schweinitz, of Bethlehem, Penn., placed in his hands and desired him to edit, during the author's absence in Europe, his Monograph of North American Carices. It was published in the Annals of the New York Lyceum, in 1825, much extended, indeed almost wholly rewritten, and so much to Schweinitz's satisfaction that he insisted that this classical monograph "should be considered and quoted in all respects as the joint production of Dr. Torrey and himself." Ten or eleven years later, in the succeeding volume of the Annals of the New York Lyceum, appeared Dr. Torrey's elaborate Monograph of the other North American

Cyperaceæ, with an appended revision of the Carices, which meanwhile had been immensely increased by the collections of Richardson, Drummond, etc., in British and Arctic America. A full set of these was consigned to his hands for study (along with other important collections), by his friend Sir William Hooker, upon the occasion of a visit which he made to Europe in 1833. But Dr. Torrey generously turned over the Carices to the late Professor Dewey, whose rival Caricography is scattered through forty or fifty volumes of the American Journal of Science and Arts: and so had only to sum up the results in this regard, and add a few Southern species at the close of his own monograph of the order.

About this time, namely, in the year 1836, upon the organization of a geological survey of the State of New York upon an extensive plan, Dr. Torrey was appointed Botanist, and was required to prepare a Flora of the State. A laborious undertaking it proved to be, involving a heavy sacrifice of time, and postponing the realization of long-cherished plans. But in 1843, after much discouragement, the Flora of the State of New York, the largest if by no means the most important of Dr. Torrey's works, was completed and published, in two large quarto volumes, with one hundred and sixty-one plates. No other State of the Union has produced a Flora to compare with this. The only thing to be regretted is that it interrupted, at a critical period, the prosecution of a far more important work.

Early in his career Dr. Torrey had resolved to undertake a general flora of North America, or at least of the United States, arranged upon the natural system, and had asked Mr. Nuttall to join him, who, however, did not consent. At that time, when little was known of the regions west of the valley of the Mississippi, the ground to be covered and the materials at hand were of comparatively moderate compass; and in aid of the northern part of it, Sir William Hooker's Flora of British America—founded upon the rich collections of the Arctic explorers, of the Hudson Bay Company's intelligent officers, and of such hardy and enterprising pioneers as Drummond and Douglas—was already in progress. At the actual inception of the enterprise, the botany of Eastern Texas was opened by Drummond's collections, as well as that of the coast of California by those of Douglas, and afterward those of Nuttall. As they clearly belonged to our own phyto-geographical province, Texas and California were accordingly annexed botanically before they became so politically.

While the field of botanical operations was thus enlarging, the time which could be devoted to it was restricted. In addition to his chair in the Medical College, Dr. Torrey had felt obliged to accept a similar one at Princeton College, and to all was now added, as we have seen, the onerous post of State Botanist. It was in the year 1836 or 1837 that he invited the writer of this notice—then pursuing botanical studies under his auspices and direction—to become his associate in the Flora of North America. In July and in October, 1838, the first two parts, making half of the first volume, were published. The great need of a full study of the sources and originals of the earlier-published species was now apparent; so, during the following year, his associate occupied himself with this work in the principal herbaria of Europe. The remaining half of the first volume appeared in June, 1840. The first part of the second volume followed in 1841; the second in the spring of 1842; and in February, 1843, came the third and the last; for Dr. Torrey's associate was now also immersed in professorial duties and in the consequent preparation of the works and collections which were necessary to their prosecution.

From that time to the present the scientific exploration of the vast interior of the continent has been actively carried on, and in consequence new plants have poured in year by year in such numbers as to overtask the powers of the few working botanists of the country, nearly all of them weighted with professional engagements. The most they could do has been to put collections into order in special reports, revise here and there a family or a genus monographically, and incorporate new materials into older parts of the fabric, or rough-hew them for portions of the edifice yet to be constructed. In all this Dr. Torrey took a prominent part down almost to the last days of his life. Passing by various detached and scattered articles upon curious new genera and the like, but not forgetting three admirable papers published in the Smithsonian Contributions to Knowledge (Plantæ Fremontianæ, and those on *Batis* and *Darlingtonia*), there is a long series of important, and some of them very extensive, contributions to the reports of government explorations of the Western country; from that of Long's expedition already referred to, in which he first developed his powers, through those of Nicollet, Fremont, and Emory, Sitgreaves, Stansbury, and Marcy, and those contained in the ampler volumes of the Surveys for Pacific Railroad routes, down to that of the Mexican Boundary, the botany of which forms a bulky quarto volume, of much interest. Even at the last, when he rallied transiently from the fatal attack, he took in hand the manuscript of an elaborate report on the plants collected along our Pacific coast in Admiral Wilkes's celebrated expedition, which he had prepared fully a dozen years ago, and which (except as to the plates) remains still unpublished through no fault of his. There would have been more to add, perhaps of equal importance, if Dr. Torrey had been as ready to complete and publish, as he was to investigate, annotate, and sketch. Through undue diffidence and a constant desire for a greater perfection than was at that time attainable, many interesting observations have from time to time been anticipated by other botanists.

All this botanical work, it may be observed, has reference to the Flora of North America, in which, it was hoped, the diverse and separate materials and component parts, which he and others had wrought upon, might some day be brought together in a completed system of American botany.

It remains to be seen whether his surviving associate of nearly forty years will be able to complete the edifice. To do this will be to supply the most pressing want of the science, and to raise the fittest monument to Dr. Torrey's memory.

In the estimate of Dr. Torrey's botanical work, it must not be forgotten that it was nearly all done in the intervals of a busy professional life; that he was for more than thirty years an active and distinguished teacher, mainly of chemistry, and in more than one institution at the same time; that he devoted much time and remarkable skill and judgment to the practical applications of chemistry, in which his counsels were constantly sought and too generously given; that when, in 1857, he exchanged a portion, and a few years later the whole, of his professional duties for the office of United States Assayer, these requisitions upon his time became more numerous and urgent.[1] In addition to the ordinary

[1] It ought to be added, that, when the Government Assay Office at New York was established, the Secretary of the Treasury selected Dr. Torrey

duties of his office, which he fulfilled to the end with punctilious faithfulness (signing the last of his daily reports upon the very day of his death, and quietly telling his son and assistant that he need not bring him any more), he was frequently requested by the head of the Treasury Department to undertake the solution of difficult problems, especially those relating to counterfeiting, or to take charge of some delicate or confidential commission, the utmost reliance being placed upon his skill, wisdom, and probity.

In two instances these commissions were made personally gratifying, not by pecuniary payment, which, beyond his simple expenses, he did not receive, but by the opportunity they afforded to recruit failing health and to gather floral treasures. Eight years ago he was sent by the Treasury Department to California, by way of the Isthmus; last summer he went again across the continent; and in both cases enjoyed the rare pleasure of viewing in their native soil, and plucking with his own hands, many a flower which he had himself named and described from dried specimens in the herbarium, and in which he felt a kind of paternal interest. Perhaps this interest culminated last summer, when he stood on the flank of the lofty and beautiful snow-clad peak to which a grateful former pupil and ardent explorer, ten years before, gave his name, and gathered charming alpine plants which he had himself named fifty years before, when the botany of the Colorado Rocky Mountains was first opened. That age and fast-failing strength had not dimmed his enjoyment, may be inferred from his remark when, on his return from Florida the previous spring, with a grievous cough allayed, he was rallied for having gone to seek Ponce de Leon's Fountain of Youth. "No," said he, "give me the Fountain of Old Age. The longer I live, the more I enjoy life." He evidently did so. If never robust, he was rarely ill, and his last sickness brought little suffering and no diminution of his characteristic cheerfulness. To him, indeed, never came the "evil days" of which he could say, "I have no pleasure in them."

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to be its Superintendent; which would have given to the establishment the advantage of a scientific head. But Dr. Torrey resolutely declined the less laborious and better paid post, and took in preference one the emoluments of which were much below his worth and the valuable extraneous services he rendered to the government; simply because he was unwilling to accept the care and responsibility of treasure.

Evincing in age much of the ardor and all of the ingenuousness of youth, he enjoyed the society of young men and students, and was helpful to them long after he ceased to teach; if, indeed, he ever did cease. For, as Emeritus Professor in Columbia College (with which his old Medical School was united), he not only opened his herbarium, but gave some lectures almost every year, and as a trustee of the College for many years he rendered faithful and important service. His large and truly invaluable herbarium, along with a choice botanical library, he several years ago made over to Columbia College, which charges itself with its safe preservation and maintenance.

Dr. Torrey leaves three daughters, a son, who has been appointed United States Assayer in his father's place, and a grandson.

This sketch of Dr. Torrey's public life and works, which it is our main duty to exhibit, would fall short of its object if it did rot convey, however briefly and incidentally, some just idea of what manner of man he was. That he was earnest, indefatigable, and able, it is needless to say. His gifts as a teacher were largely proved and are widely known through a long generation of pupils. As an investigator, he was characterized by a scrupulous accuracy, a remarkable fertility of mind, especially as shown in devising ways and means of research, and perhaps by some excess of caution.

Other biographers will doubtless dwell upon the more personal aspects and characteristics of our distinguished and lamented associate. To them, indeed, may fittingly be left the full delineation and illustration of the traits of a singularly transparent, genial, delicate, and conscientious, unselfish character, which beautified and fructified a most industrious and useful life, and won the affection of all who knew him. For one thing, they cannot fail to notice his thorough love of truth for its own sake, and his entire confidence that the legitimate results of scientific inquiry would never be inimical to the Christian religion, which he held with an untroubled faith, and illustrated, most naturally and unpretendingly, in all his life and conversation. In this, as well as in the simplicity of his character, he much resembled Faraday.

Dr. Torrey was an honorary or corresponding member of a goodly number of the scientific societies of Europe, and was naturally connected with all prominent institutions of the kind in this country. He was chosen into the American Academy in the year 1841. He was one of the corporate members of the National Academy at Washington. He presided in his turn over the American Association for the Advancement of Science. He was twice, for considerable periods, President of the New York Lyceum of Natural History, which was in those days one of the foremost of our scientific societies. It has been said of him that the sole distinction on which he prided himself was his membership in the order of the Cincinnati, the only honor in this country which comes by inheritance.

As to the customary testimonial which the botanist receives from his fellows, it is fortunate that the first attempts were nugatory. Almost in his youth a genus was dedicated to him by his correspondent, Sprengel: this proved to be a *Clerodendron*, misunderstood. A second, proposed by Rafinesque, was founded on an artificial dismemberment of *Cypreus*. The ground was clear, therefore, when, thirty or forty years ago, a new and remarkable evergreen tree was discovered in our own Southern States, which it was at once determined should bear Dr. Torrey's name. More recently a congener was found in the noble forests of California. Another species had already been recognized in Japan, and lately a fourth in the mountains of Northern China. All four of them have been introduced, and are greatly prized as ornamental trees in Europe. So that, all round the world, *Torreya taxifolia, Torreya Californica, Torreya nucifera,* and *Torreya grandis*—as well as his own important contributions to botany, of which they are a memorial—should keep our associate's memory as green as their own perpetual verdure.

MEMOIR

OF

WILLIAM STARLING SULLIVANT.

1803-1873.

BY

ASA GRAY.

READ BEFORE THE NATIONAL ACADEMY, APRIL 22, 1875.

BIOGRAPHICAL MEMOIR

OF

WILLIAM STARLING SULLIVANT.

William Starling Sullivant, LL.D., died at his residence in Columbus, Ohio, on the 30th of April, ultimo. In him we lose the most accomplished bryologist which this country has produced; and it can hardly be said that he leaves behind anywhere a superior.

He was born, January 15, 1803, at the little village of Franklinton, then a frontier settlement in the midst of primitive forest, near the site of the present city of Columbus. His father, a Virginian, and a man of marked character, was appointed by government to survey the lands of that district of the "Northwestern Territory" which became the central part of the now populous State of Ohio; and he early purchased a large tract of land, bordering on the Scioto River, near by, if not including, the locality which was afterward fixed upon for the State capital.

William, his eldest son, in his boyhood, if he endured some of the privations, yet enjoyed the advantages of this frontier life, in the way of physical training and early self-reliance. But he was sent to school in Kentucky; he received the rudiments of his classical education at the Ohio University at Athens, upon the opening of that institution; and was afterward transferred to Yale College, where he was graduated in the year 1823. His plans for studying a profession were frustrated by the death of his father in that year. This required him to occupy himself with the care of the family property, then mainly in lands, mills, etc., and demanding much and varied attention. He became surveyor and practical engineer, and indeed took an active part in business down to a recent period. Leisure is hardly to be had in a newly settled country, and least of all by those who have possessions. Mr. Sullivant must have reached the age of nearly thirty years, and, having married early,[1] was established in his suburban residence in a rich floral district, before his taste for natural history was at all developed. His youngest brother, Joseph, was already somewhat proficient in botany as well as in conchology and ornithology; and when in some way his own interest in the subject was at length excited, he took it up with characteristic determination to know well whatever he undertook to know at all. He collected and carefully studied the plants of the central part of Ohio, made neat sketches of the minuter parts of many of them, especially of the Grasses and Sedges, entered into communication with the leading botanists of the country, and in 1840 he published "A Catalogue of Plants, Native or Naturalized, in the Vicinity of Columbus, Ohio," pp. 63, to which he added a few pages of valuable notes. His only other direct publication in phænogamous botany is a short article upon three new plants which he had discovered in that district, contributed to the American Journal of Science and Arts, in the year 1842. The observations which he continued to make were communicated to his correspondents and friends, the authors of the "Flora of North America," then in progress. As soon as the flowering plants of his district had ceased to afford him novelty, he turned to the Mosses, in which he found abundant scientific occupation, of a kind well suited to his bent for patient and close observation, scrupulous accuracy, and nice discrimination. His first publication in his chosen department, the "Musci Alleghanienses," was accompanied by the specimens themselves of Mosses and Hepaticæ collected in a botanical expedition through the Alleghany Mountains from Maryland to Georgia, in the summer of 1843, the writer of this notice being his companion. The specimens were not only critically determined, but exquisitely prepared and mounted, and with letter-press of great perfection; the whole forming two quarto volumes, which well deserve the

[1] His first wife, Jane Marshall of Kentucky, was a niece of Chief Justice Marshall. She died within a year after marriage.

encomium bestowed by Pritzel in his Thesaurus.[1] It was not put on sale, but fifty copies were distributed with a free hand among bryologists and others who would appreciate it.[2]

In 1846, Mr. Sullivant communicated to the American Academy the first part, and in 1849 the second part, of his "Contributions to the Bryology and Hepaticology of North America," which appeared, one in the third, the other in the fourth volume (new series) of the Academy's Memoirs; each with five plates from the author's own admirable drawings. These plates were engraved at his own expense, and were generously given to the Academy.

When the second edition of Gray's "Manual of the Botany of the Northern United States" was in preparation, Mr. Sullivant was asked to contribute to it a compendious account of the Musci and Hepaticæ of the region; which he did, in the space of about one hundred pages, generously adding, at his sole charge, eight copperplates crowded with illustrations of the details of the genera; thus enhancing vastly the value of his friend's work, and laying a foundation for the general study of bryology in the United States, which then and thus began.

So excellent are these illustrations, both in plan and execution, that Schimper, then the leading bryologist of the Old World, and a most competent judge, since he has published hundreds of figures in his "Bryologia Europæa," not only adopted the same plan in his Synopsis of the European Mosses, but also the very figures themselves (a few of which were, however, originally his own), whenever they would serve his purpose, as was the case with most of them. A separate edition was published of this portion of the Manual, under the title of "The Musci and Hepaticæ of the United States, east of the Mississippi River" (New York, 1856, imperial octavo), upon thick paper, and with proof-impressions directly from the copperplates. This exquisite

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[1] "Huic splendidæ impressæ 292 specierum enumerationi accedit elegantissima speciminum omnium exsiccatorum collectio."

[2] A tribute is justly due to the memory of the second Mrs. (Eliza G. Wheeler) Sullivant, a lady of rare accomplishments, and, not least, a zealous and acute bryologist, her husband's efficient associate in all his scientific work until her death, of cholera, in 1850 or 1851. Her botanical services are commemorated in *Hypnum Sullivantiæ* of Schimper, a new Moss of Ohio.

volume was placed on sale at far less than its cost, and copies are now of great rarity and value. It was with regret that the author of the Manual omitted this cryptogamic portion from the ensuing editions, and only with the understanding that a separate "Species Muscorum," or Manual for the Mosses of the whole United States, should replace it. This most needful work Mr. Sullivant was just about to prepare for the press.

About the same time that Mr. Sullivant thus gave to American students a text-book for our Mosses, he provided an unequalled series of named specimens for illustrating them. The ample stores which he had collected or acquired, supplemented by those collected by M. Lesquereux (who was associated with him from the year 1848) in a journey through the mountainous parts of the Southern States under his auspices, after critical determination were divided into fifty sets, each of about three hundred and sixty species or varieties, with printed tickets, title, index, etc., and all, except a few copies for gratuitous distribution, were generously made over, to be sold at less than cost, for his esteemed associate's benefit, and, still more, that of the botanists and institutions who could thus acquire them. The title of this classical work and collection is, "Musci Boreali Americani quorum specimina exsiccati ediderunt W. S. Sullivant et L. Lesquereux; 1856." Naturally enough the edition was immediately taken up.

In 1865 it was followed by a new one, or, rather, a new work, of between five and six hundred numbers, many of them Californian species, the first-fruits of Dr. Bolander's researches in that country. The sets of this unequalled collection were disposed of with the same unequalled liberality, and with the sole view of advancing the knowledge of his favorite science. This second edition being exhausted, he recently and in the same spirit aided his friend Mr. Austin, both in the study and in the publication of his extensive "Musci Appalachiani."

To complete here the account of Mr. Sullivant's bryological labors illustrated by "exsiccati," we may mention his "Musci Cubenses," named, and the new species described in 1861, from Charles Wright's earlier collections in Cuba, and distributed in sets by the collector. His researches upon later and more extensive collections by Mr. Wright lie in the form of notes and pencil sketches, in which many new species are indicated. The same may be said of an earlier still unpublished collection, made by Fendler in Venezuela. Another collection, of great extent and interest, which was long ago elaborately prepared for publication, and illustrated by very many exquisite drawings, rests in his portfolios, through delays over which Mr. Sullivant had no control; namely, the Bryology of Rodgers's U. S. North Pacific Exploring Expedition, of which Charles Wright was botanist. Brief characters of the principal new species were, however, duly published in this as in other departments of the botany of that expedition. It is much to be regretted that the drawings which illustrate them have not yet been engraved and given to the scientific world.

This has fortunately been done in the case of the South Pacific Exploring Expedition under Commodore Wilkes. For, although the volume containing the Mosses has not even yet (May, 1873) been issued by government, Mr. Sullivant's portion of it was published in a separate edition in the year 1859. It forms a sumptuous imperial folio, the letter-press having been made up into large pages, and printed on paper which matches the plates, twenty-six in number.

One volume of the Pacific Railroad Reports, *i. e.*, the fourth, contains a paper by Mr. Sullivant, being his account of the Mosses collected in Whipple's Exploration. It consists of only a dozen pages of letter-press, but is illustrated by ten admirable plates of new species.

The "Icones Muscorum," however, is Mr. Sullivant's crowning work. It consists, as the title indicates, of "Figures and Descriptions of most of those Mosses peculiar to Eastern North America which have not been heretofore figured," and forms an imperial octavo volume, with one hundred and twenty-nine copper-plates, published in 1864. The letter-press and the plates (upon which last alone several thousand dollars and immense pains were expended) are simply exquisite and wholly unrivalled; and the scientific character is acknowledged to be worthy of the setting. Within the last few years, most of the time which Mr. Sullivant could devote to science has been given to the preparation of a second or supplementary volume of the "Icones." The plates, it is understood, are completed, the descriptions partly written out, and the vernal months in which his mortal life closed were to have been devoted to the printing. The Manual of North American Mosses was speedily to follow.

He was remarkably young for his years, so that the hopes and expectations in which we were indulging seemed reasonable. But in January, not far from his seventieth birthday, he was prostrated by pneumonia, from the consequences of which, after some seeming convalescence, he died upon the last day of April. He leaves a wife, Mrs. Caroline E. (Sutton) Sullivant, children, grandchildren, and great-grandchildren, to inherit a stainless and honored name, and to cherish a noble memory.

In personal appearance and carriage, no less than in all the traits of an unselfish and well-balanced character, Mr. Sullivant was a fine specimen of a man. He had excellent business talents, and was an exemplary citizen; he had a refined and sure taste, and was an accomplished draughtsman. But after having illustrated his earlier productions with his own pencil, he found that valuable time was to be gained by employing a trained artist. He discovered in Mr. A. Schrader a hopeful draughtsman, and he educated him to the work, with what excellent results the plates of the "Icones" and of his other works abundantly show. As an investigator he worked deliberately, slowly indeed and not continuously, but perseveringly. Having chosen his particular department, he gave himself undeviatingly to its advancement. His works have laid such a broad and complete foundation for the study of bryology in this country, and are of such recognized importance everywhere, that they must always be of classical authority; in fact, they are likely to remain for a long time unrivalled. Wherever Mosses are studied, his name will be honorably remembered; in this country it should long be remembered with peculiar gratitude.

In accordance with his wishes, all his bryological books and his exceedingly rich and important collections and preparations of Mosses are to be consigned to the Gray Herbarium of Harvard University, with a view to their safe preservation and long-continued usefulness. The remainder of his botanical library, his choice microscopes, and other collections are bequeathed to the State Scientific and Agricultural College, just established at Columbus, and to the Starling Medical College, founded by his uncle, of which he was himself the Senior Trustee.

Mr. Sullivant was chosen into the American Academy in the year 1845. He received the honorary degree of Doctor of Laws from Gambier College, in his native State, and was an associate of the principal scientific societies of this country, and of several in Europe. His oldest botanical associates long ago enjoyed the pleasure of bestowing the name of SULLIVANTIA OHIONIS upon a very rare and interesting, but modest and neat Saxifragaceous plant, which he himself discovered in his native State, on the secluded banks of a tributary of the river which flows by the place where he was born, and where his remains now repose.

MEMOIR

OF

JOSEPH SAXTON.

1799–1873.

BY

JOSEPH HENRY.

READ BEFORE THE NATIONAL ACADEMY, OCT. 4, 1874.

BIOGRAPHICAL MEMOIR OF JOSEPH SAXTON.

MR. PRESIDENT AND GENTLEMEN OF THE ACADEMY:—

AT the last session of the National Academy of Sciences I was appointed to prepare an account of the life and labors of our lamented associate, Joseph Saxton, whose death we have been called to mourn. From long acquaintance and friendly relations with the deceased, the discharge of the duty thus devolved upon me has been a labor of love, but had he been personally unknown to me, the preparation of the eulogy would have been none the less a sacred duty, which I was not at liberty on any account to neglect. It is an obligation we owe to the Academy and the world to cherish the memory of our departed associates; their reputation is a precious inheritance to the Academy which exalts its character and extends its usefulness.

Man is a sympathetic and imitative being, and through these characteristics of his nature the memories of good men produce an important influence on posterity, and therefore should be cherished and perpetuated. Moreover, the certainty of having a just tribute paid to our memory after our departure is one of the most powerful inducements to purity of life and propriety of deportment.

The object of the National Academy is the advancement of science, and no one is considered eligible for membership who has not made positive additions to the sum of human knowledge, or in other words, has not done something to entitle him to the appellation of scientific.

Joseph Saxton, the subject of our eulogy, was named in the Act of Congress organizing the Academy, one of its fifty original members, and I trust the following sketch of his life and labors, imperfect as it may be, will fully justify the propriety of the distinction which was thus conferred upon him.

He was born in Huntingdon, Pennsylvania, then a small village, on the banks of the Juniata, on the 22d of March, 1799, and died in the city of Washington, October 26th, 1873. He lived, therefore, within five months of three-quarters of a century. During his life the world made greater progress in the application of science to art than in any other period of equal length in all of its previous history. To illustrate this remark I have only to recall the fact that during this period the steamboat, the railway, the locomotive, the electric telegraph, the photograph, and the spectroscope had their birth.

It might be an interesting inquiry to determine what effect was produced on his character by the direction of the energy and the prevailing thought of the age in which he lived. Be this as it may, our associate found in the period of his life congenial tendencies, and he had the good fortune, denied to many, of neither being behind nor in advance of his age, but of being in perfect harmony with it. He neither pestered the world with premature projects destined to failure because the necessary contemporaneous conditions were not present; nor retarded the advance of improvement by advocating old errors under new forms. On the contrary, his inventions were founded on well-established principles, and consequently were positive additions to human power and efficiency.

Mr. Saxton in early life had few advantages of education, nothing more than what was afforded by an ordinary common school, but he possessed a mind of general powers which enabled him to grapple with a large class of subjects; and an imagination which teemed with new conceptions, especially in the form of scientific inventions. Whether these traits had been especially manifested in any of his progenitors, I have no means of ascertaining. His father was James Saxton, who with his wife Hannah Ashbaugh, was the parent of eleven children, of whom the subject of our sketch was the second. James Saxton, the father, was a man of talents, but did not apparently apply them persistently to one pursuit. He occupied in succession the position of an assistant in a banking establishment, a justice of the peace, and that of a proprietor of a nail manufactory, the first ever erected in the part of the country in which he resided. He was of English descent, his wife belonged to one of the German families of Pennsylvania, and was noted for her good common sense and efficient housekeeping.

At the age of about twelve years Joseph was put into his father's nail factory as a working hand, and soon evinced his talent for invention by an improvement in the machinery which added materially to its efficiency.

Becoming discontented with the monotony and mechanical drudgery of the nail factory, at his earnest solicitation he was apprenticed to the village watchmaker, but after being in this occupation for about two years he was thrown out of it by the death of his employer.

After this he amused himself with the construction of a printing-press and the publication of a small newspaper, irregularly issued. His first speculation in the line of science was an attempt to explain an accident which nearly cost him his life. He had become the possessor of a new rifle, and on loading it for the first time, after putting in the powder and inserting the ball covered with its greased patch, he found to his surprise that, on attempting to push down the ball with the ramrod, it sprung back, in one instance with such velocity as to project the rod out of the barrel. Determining to force down the ball whatever the resistance might be, he placed the projecting end of the rod against the trunk of a tree, and then with the momentum acquired by the weight of the gun gave a powerful push, which was attended with a result entirely unexpected. The ball was indeed forced in, but, in overcoming the resistance, an explosion took place, which shattered the ramrod into fragments and prostrated him at full length, almost lifeless, on the ground. Reflecting on this incident, which could not fail to make a deep impression on his mind, he came to the conclusion, probably by the analogy of the heat evolved in hammering a nail, that there is heat in the air, and that, by the violent pressure to which he had subjected it in attempting to urge down the ball, he had pressed out this heat, and thus fired the powder.

Learning by subsequent inquiry that his hypothesis was in accordance with received principles of science, he was naturally awakened to the consciousness of the possession of powers of original thought—a discovery which was undoubtedly attended with pleasurable emotions, and which would in no small degree promote self-confidence.

He had now arrived at the age of eighteen. Conscious of mental power, and desirous of extending his sphere of action and his means of acquiring knowledge, he resolved to leave his home and seek his fortune in Philadelphia, the fame of which had often excited his youthful imagination. In this enterprise he induced two of his companions of about the same age as himself to join. They first repaired a boat which he had previously constructed as a large model of a man-of-war, and, after furnishing it with a supply of provisions and placing on board all their worldly effects, they launched forth, and were rapidly borne by the current of the river on their adventurous voyage, with but little need of aid from oar or sail. The news of the intended departure of the trio produced in the isolated village of Huntingdon quite a sensation, and called forth much discussion as to the probability of the project being abandoned before the adventurers had passed the neighboring settlement, five miles below. Indeed, so great an interest was awakened in this question that a considerable number of their friends and acquaintances accompanied them along the bank to the village just mentioned with the expectation of seeing them give up what appeared to be a foolhardy undertaking. But this occurrence served but the more to induce perseverance; for, although they were probably oppressed with sadness at leaving home and friends, with no definite prospect before them, they were sustained by their pride of consistency, and were soon carried by the current out of sight of their followers. They reached, without any incident worthy of notice, the city of Harrisburg, but here the river became so turbulent that navigation in the boat was no longer practicable, and, as their provisions were exhausted and their pockets but sparingly supplied with the means of procuring more, they sought a purchaser for the boat, and after some difficulty found one in the person of the landlord of a small German tavern, who agreed to give for it ten dollars in cash, with supper, breakfast, and a night's lodging for the party. The bargain, however, came near being cancelled on the part of the landlord, who, being a heavy man and eager to test the capacity of his purchase, imprudently stepped on the side of the boat as it floated near the wharf, and was immediately plunged beneath the surface of deep water, from which he was with difficulty saved from drowning through the assistance of the trio. Disgusted with his first essay with the boat, he declared that it was an uncertain craft, of which he would not be the owner; fortunately, however, after having recovered from his fright, and been provided by his wife with dry clothes, he concluded to stand by his engagement.

The next morning our travellers started at an early hour to accomplish the remainder of the journey on foot; and in due time, with a prudent use of the money obtained from the sale of the boat, arrived in Philadelphia. Here they separated, each to commence the battle of life for himself, with what result, except in the case of young Saxton, we are not informed.

He was provided with a letter from a friend in his native village, commending him in warm terms to a watchmaker in Chestnut Street. This person gave him employment for some time, when he left the business of watchmaking to become an engraver. In this employment he learned to draw with facility, and to sketch from nature with considerable effect. While with the watchmaker, he invented a machine for cutting the teeth of wheels, the outlines of which were true epicycloidal curves. This invention, which evinced profound thought and remarkable ingenuity, is of great value in the construction of chronometer wheels, as well as those of all other kinds of machinery.

He remained but a comparatively short time in the study of the art of engraving, and next became associated with Isaiah Lukens, a celebrated machinist of Philadelphia, who was noted in all parts of the United States for having detected the imposition in the Red-heifer machine, which had attracted much attention as a working perpetual-motion. While associated with Lukens, he constructed an astronomical clock with a compensating pendulum, and an escapement on a new plan devised by himself. This clock kept excellent time, and is, I am informed, still in good condition. He also constructed the town clock for the city of Philadelphia, which continues until the present day to proclaim the passing hours from the belfry of Independence Hall.

He acquired in Philadelphia a reputation for great ingenuity, and was elected a member of the Franklin Institute, an establishment then just commencing its careér, and which still preserves a vigorous and active existence, after having done more than any other institution for the advancement of the economical and mechanical arts in this country. In this society he became associated with Prof. Bache, G. W. Smith, Fred. Fraley, Prof. Cresson, J. V. Merrick, and a host of other young and enterprising men who have all performed important parts in the drama of life.

Impelled by a desire to enlarge his knowledge, he resolved to visit England, and for this purpose carefully hoarded his income. On his arrival in London, he placed his money in charge of a banking-house, which shortly after stopped payment, and left him amid the social solitude of an immense city of strangers, without friends, acquaintances, or the means of adequate support. He was not, however, destined to remain long in this condition. He soon made himself known at a new institution, called the Adelaide Gallery of Practical Science, an establishment founded in 1831, for the purpose of exhibiting scientific novelties, to illustrate scientific subjects, and to afford discoverers, inventors, and manufacturers an opportunity to bring before the public their works in an attractive and interesting manner. This Gallery, besides an extended series of philosophical apparatus, contained a class of objects which would afford amusement as well as instruction. Such was the Persian rope-dancer and the oriental magician, which were never-failing objects of admiration to the young as well as to the more advanced in age who were led to inquire into their ingenious and elaborate mechanism.

The first contribution which Mr. Saxton made to this institution belonged to the class we have just mentioned. It was denominated the "paradoxical head." This consisted of the figure of the head and bust of a Turk, carved with artistic skill, around the otherwise naked neck of which was a black ribbon, having what appeared to be a seam along the middle of its length. The head and the bust were apparently carved from one piece, and yet, to the surprise of the beholders, a dexterous master of fence would, after a few flourishes of a thin sword, pass the blade through the neck, apparently severing the head from the body, yet without disturbing the connection. This toy attracted great attention, and gave rise to much speculation as to the plan of its construction. By many the connection was supposed to be maintained by magnetism. This, however, was not the true explanation. The effect was produced by an ingenious arrangement of mechanism, which enabled the blade of the sword, in its passage through the neck, to unlock and lock in succession a series of catches, leaving the same connection after as before the passage of the blade.

The Adelaide Gallery was at the time one of the chief objects of interest of the British metropolis. The exhibition of the paradoxical head led to the employment of Mr. Saxton in various ways to add to the attractions of the gallery. He constructed for it a compound steel magnet which sustained the weight of 525 pounds, and also a magnetic needle of several feet in length with a mirror on its end, which exhibited for the first time by the movement of a reflected beam of light, on a magnificent scale, the daily and hourly variations of the magnetic force of the earth. He also added to the attractions of the gallery various interesting objects, such as a series of miniature vessels of various forms apparently sailing with a fair wind on the surface of an artificial lake, although impelled by ingenious contrivances of clock work in the depth of the water. He also fitted up a diving bell with glass sides in which visitors were sent to the bottom of a deep tank.

In connection with the Adelaide Gallery he soon became intimately acquainted and lived on terms of friendly intercourse with some of the most celebrated engineers and mechanicians of the day. Among these were Telford, Brunel, Whitwell, Hawkins, and others, whose names are associated with some of the proudest monuments of English engineering. Through the influence of these gentlemen, he was introduced to the meetings of the Royal Institution, and admitted into friendly relationship with the presiding genius of that establishment, the world-renowned Michael Faraday. In such association, he breathed a congenial atmosphere, his peculiar faculties being exercised to the utmost; and, stimulated by the applause of enlightened appreciation, his mind teemed with new suggestions.

For several years, about this time, he kept a diary in which he recorded daily events intermingled with suggestions which illustrated his habits, his thoughts, and his varying employment. From this record which has been placed in my hands for perusal, it is evident that he was a critical observer; that his sympathies were many sided; that he kept himself posted in the occurrences of the day, and systematically devoted a portion of time to reading the newspapers and the scientific journals of the period; that he took a lively interest in the passage of the celebrated reform bill, then under discussion; and was always alive to every item of news from America. For although he was living under the protection of a foreign government, he ever cherished an ardent attachment to the institutions of his own country; indeed his patriotism was a marked trait of his character, which evinced itself in our late civil war by the warmth of his expressions in favor of the Union. It was during the time we have mentioned that he made his great scientific invention of the magneto-electric machine. Dr. Faraday in 1831 had discovered the primary facts of electro-dynamic induction, and also those of magneto-electricity. He had shown, first, that, when two insulated conducting wires are placed near, and parallel to each other, and a current of electricity is passed through one of the wires, an induced current will be excited for an instant in the other wire, and in an opposite direction to the inducing current. Furthermore, at the cessation of the primary current, an induced current will take place in the same direction as the primary. These are the fundamental facts of electro-dynamics. The analogous facts of magneto-electricity are as follows: If an insulated wire be coiled into the form of a helix, and into this helix a permanent magnet be thrust, a current of electricity will circulate for an instant through the wire; while the magnet remains at rest within the coil no electrical phenomena are observed; but during the act of drawing out the magnet, an induced current in the opposite direction will be produced. The two sets of analogous phenomena fall into the same class, if we adopt the theory of Ampère, that the magnetism of a bar of steel consists of a series of currents of electricity revolving around the atoms of the magnet at right angles to its length. The existence of these currents of induction was indicated by Mr. Faraday in the motion of a delicate galvanometer. These discoveries were the intimations of the hitherto unknown action of all-pervading forces, which required clear conception, and ingenious combinations to call them forth, as it were, with palpable energy; and to do this was the task which Mr. Saxton essayed. The solution of the problem was one of great difficulty. The current or induction existed but for the fraction of a second, and in that time gradually increased from nothing up to a maximum and then declined. The problem was to exhibit this current at the period of its greatest quantity and intensity, and for this purpose it was necessary to break the closed circuit in which it moved at the critical moment, to close it again at the proper time, and so on. These requisites were admirably provided for by the simplest possible arrangements, which could only have been invented by one who had a clear and definite conception of the nature of the force to be developed and an imagination to suggest the means by which the result was to be accomplished. Success was, however, obtained by Mr. Saxton apparently without much mental effort, and the encountering of any great difficulties.

It was a part of the general principle discovered by Mr. Faraday that, if an insulated or coated wire were wound with many coils around a cylinder of soft iron, which is suddenly magnetized by touching its end with a magnet, the same effect would be produced as that described by thrusting in and drawing out a permanent magnet. A current in one direction would be excited in the coil when the core became magnetized, and a current would be produced in an opposite direction the moment the magnetism ceased. Mr. Saxton adopted for the inducing magnet to be employed in his machine, a compound one consisting of a number of steel bars bent into the form of a horseshoe, magnetized separately; and then screwed together so as to form one powerful combination. For the inducing part of the apparatus, he bent a cylindrical rod of iron of about three-fourths of an inch in diameter twice at right angles so as to produce the form of a U, the parallel legs of which were at the distance of that of the centres of the two poles of the permanent magnet. Around each of these legs he wound 30 or 40 yards of insulated copper-wire. Now it is evident from the principle before stated that when the two ends of the legs of this U of soft iron are brought in contact with the poles of the permanent magnet, an instantaneous current will be produced in the natural electricity of the wires, each in a direction opposite to the other. Again, when the soft iron U is drawn suddenly away from the poles of the permanent magnet, a reverse current will take place in each of the coils. But a more intense effect will be produced if the legs of the soft iron horseshoe or U be made to rotate before the face or poles of the permanent magnet, so as to slide off of one on to the other. In this case the effect will be double that of separating it simply from a single pole; since, if, in passing from the first pole it loses its magnetism, in passing on to the second it may be considered as being de-magnetized still further since it is changed into the opposite magnetism. A similar result will be produced with the other leg of the horseshoe. To excite, therefore, the greatest possible amount of electrical induction, Mr. Saxton fastened the U to a revolving axis passing through its crown, to which a rapid rotation could be given by means of a driving wheel and pulley. In order, however, to obtain manifestations of the induced currents produced in the copper-wire, the two ends of the coils were so soldered together, as to give a single current in one direction through the entire length of the coils. One of the remaining ends was then permanently soldered to a circular disk fastened concentrically to the revolving axis by an insulating collar, with its plane perpendicular to it. This plate dipped into a cup of mercury. The other end of the wire was soldered directly to the revolving shaft or axis. In this arrangement the insulated disk formed one pole of the long wire, and the revolving shaft the other; but as they were not connected, no electrical excitement was observed when the bobbins were revolved. To make and break the connection at the proper moment, two wires were soldered diametrically opposite each other on a ferule which fitted tightly with friction on the revolving shaft. These wires standing out at right angles to the shaft were cut off at such a length, that at each revolution, the ends would plunge into the same cup of mercury with the revolving disk, and thus complete and break the circuit twice with each revolution of the bobbins. These wire points were then so adjusted by turning the ferule on the shaft as to cause them to enter and leave the mercury at the moment when the magnetism was increasing or diminishing most rapidly, and consequently when the current had the greatest intensity.

With this instrument he was enabled to exhibit a brilliant electrical spark, to decompose water, to show the electrical light between charcoal points, and to give a rapid series of intense shocks. The instrument was exhibited to the public for the first time at the meeting of the British Association at Cambridge in June, 1833, where it excited much interest, and was permanently placed in the Adelaide Gallery in August of the same year. The poet Coleridge, who was present at its exhibition ir Cambridge, spoke with enthusiasm, not only of the magnitud of the discovery of the inductive electrical effects of magnetisn one of the claims of Faraday—to imperishable reputation—but also of the ingenious invention of Mr. Saxton, by which the transient electrical currents might exhibit their effects in so brilliant and so powerful a manner.

Strange to say, however, no description of this instrument was published in any journal until 1836. In the August number of the *London and Edinburgh Philosophical Magazine* of that year, an instrument-maker in London by the name of Clarke published an account of a machine identical in principle with that invented by Mr. Saxton, differing from it only in a few unessential arrangements of parts—affording one of the most signal instances of unblushing piracy on record.

Saxton's reclamation was published in the October number of the same journal, and is a dignified and convincing exposition of the wrong to which he had been subjected. It is, with the exception of the description of the instrument, given in full in the following extract from the journal before mentioned:—

"I regret that I am called upon to notice a very disingenuous article in the number of the *Philosophical Magazine* for October. A reader, unacquainted with the progress which magneto-electricity has made since this new path of science was opened by the beautiful and unexpected discoveries of Faraday, might be misled, from the paper I have alluded to, to believe that the electro-magnetic machine there represented was the invention of the writer; and that the experiments there mentioned were for the first time made by its means. No conclusion, however, would be more erroneous. The machine which Mr. Clarke calls *his* invention differs from mine only in a slight variation in the situation of its parts; and is in no respect superior to it. The experiments, which he states in such a manner as to insinuate that they are capable of being made only by his machine, have every one been long since performed with my instrument; and Mr. Clarke has had every opportunity of knowing the truth of this statement.

"Though my machine is well known to the public from its constant exhibition at the Adelaide Street Gallery since August, 1833, and my claims as its inventor have been acknowledged by Professors Faraday, Daniell, and Wheatstone in papers of theirs published in the *Philosophical Transactions*, yet, as no description of it has yet been published, I will thank you to insert the following in the ensuing number of the *Philosophical Magazine*."

After giving an account of his machine, he concludes as follows:—

"In conclusion, I think it will be evident, from the preceding statement, that the magneto-electrical machine, which Mr. Clarke has brought forward 'after much anxious thought, labor, and expense,' is a piracy of mine; the piracy consisting not in manufacturing the instrument—for every one is at full liberty to do so—but in calling it an invention of his own, and suppressing all mention of my name as connected with it."

This reclamation, however convincing, was too late to prevent the introduction of the name of Clarke as the inventor of the magneto-electrical machine in the continental journals; and even in the extended history of electricity by Becquerel, the credit is given to the same person.

During Mr. Saxton's residence in London, he also invented the locomotive differential pulley, a description of which, and the method of producing rapid and uninterrupted travelling by means of a succession of such pulleys by horse power, was given by Mr. John J. Hawkins to the British Association, at its third meeting, held in Cambridge, in 1833. The fundamental principle of this may be understood by supposing motion to be given by a cord to a pulley, say six inches in diameter, around the axis of a wheel of six feet in diameter. It is evident, then, that if motion be given to the smaller pulley by unwinding the rope, the larger wheels will move with a velocity of twelve times that of the smaller wheels, or, in other words, with twelve times the velocity of the impelling rope, and give an equal velocity to another rope to which carriages may be attached. Mr. Hawkins concluded from his calculation that a continuous motion of thirty miles an hour could be given to a passenger coach by relays of horses, walking at the rate of two and a half miles an hour. A company was formed for the application of this invention on canals, but owing to the great success of steam locomotion the project was abandoned. It may, however, be yet applied in elevated railways, and under conditions in which the immediate application of steam power cannot be made.

Mr. Saxton also invented an apparatus for measuring the velocity of vessels, which was applied with a dynamometer for determining the resistance of vessels on a canal with different velocities.

It appears from his diary that at one time he had the principal charge of the apparatus of the Adelaide Gallery, and this gave him an opportunity of making observations and experiments of interest. He states that on firing a volley of lead balls from a Perkins steam gun, which was one of the objects on exhibition, against an iron target, a glow in the dark was observed of a nebulous appearance, each ball as it struck the iron emitting a flash of light. He experimented with the apparatus for condensing carbonic acid and for its use in the propulsion of balls; the result, however, did not answer his expectations. Too much of the elastic power of the substance, he says, was expended in moving itself to give the ball a comparatively great velocity. He also made experiments with the apparatus invented by Mr. Perkins for exhibiting the compressibility of water. This consisted of a strong cast-iron bottle into the neck of which a cylindrical plunger was carefully fitted, and this was forced down into the vessel when filled with water by means of a hydrostatic press. The degree of compressibility of the water was indicated by a ring on the plunger which being pushed up by the descent of the plunger retained its position by friction, and thus indicated the depth to which the rod had been projected into the water. The result of the experiments gave a much greater ratio of compressibility than was afterwards obtained by Oersted of Copenhagen.

The difference was probably due to the fact that under the great pressure to which the apparatus was subjected, a portion of the water was forced into the pores of the iron, and thereby, as it were, increased the capacity of the vessel. This explanation is rendered the more probable from an experiment made by Mr. Saxton himself, which consisted in filling a small ball of brass with thick sides, entirely with water, secured by a screw tap. This, being subjected to a temperature below freezing during a cold night, was found in the morning covered with minute filaments of ice which the expansion of the water had forced through the pores of the metal.

Mr. Saxton during his life was fond of rural sports. He was a very successful angler, and early excited the admiration of his companions by the invention of a simple instrument by which he could project his line into the middle of a rapid river, while standing on its bank. For this purpose he cut a shingle or thin board into the form of a fish, loaded one edge so that it would float vertically; from the lower edge of this he suspended lines with baited hooks; to one of the flat sides of this fish he applied three cords united in one long string, after the manner of the cords of a kite. When this instrument was thrown into the water, and the fisherman on the bank, holding the end of the long string, ran a short distance up the stream, the artificial fish would move off into the middle of the river and there remain, for the same reason that a kite ascends in the air and remains at a high altitude, under similar conditions of pressure and equilibrium.

He also amused himself with hunting, but even in this the pleasure was more in the exercise of his inventive faculties than in the gratification of the remnant of the brutal propensities which induces civilized man to the wanton destruction of animal life.

The use of ordinary instruments was not sufficient for the gratification of his tastes. He was in the habit of employing an air-gun of which the reservoir, syringe, and barrel were formed of the several parts of an ordinary sized walking cane. In the use of this instrument he was extremely expert, and could discharge a number of balls in succession through a mark on an inch board at several rods distance. He also attached a small telescope to his rifle, adjusting its axis to that of the bore, so as to insure the hitting of the target at a great distance when the cross hairs in the focus of the telescope apparently cut the bull's eye. For the use of this gun he invented what has since been a source of great emolument to the owner of a patent right: I allude to the metallic cartridge now so generally used, especially in the art of war.

In the diary which we have previously mentioned, there are accounts of various inventions which had suggested themselves to him during the mental stimulus of his life in London. Among these are the method of indicating the height of water within a steam boiler, which consisted in placing a floating hollow magnet in a copper tube; communicating at one end with the top, and at the other with the bottom of the boiler. Surrounding this tube was another of glass also containing water in which a second magnet floated, the position of which marked the height of water in the boiler. An invention similar to this has since been patented and brought into use.

Another invention was that of a fountain *pen*, which, in practice, fully realized his anticipations; another, an ever-pointed pencil, which was among the first of the various forms of this instrument of expressing thought which have since been adopted. Although his mind was more directed to the application of scientific principles than to original investigation, yet under different conditions of life and of early mental training, he would undoubtedly have excelled in this line. Besides the experiments we have already mentioned, he records a series of experiments in relation to the lateral adhesion of a current of water projected through a reservoir of the liquid, and finds in one experiment, that fourteen times as much water was thrown out of a shallow basin as was projected into it through the nozzle of a syringe, obliquely inserted under the surface.

He also gives a method of determining the position of the interior magnetic poles of the earth, by projecting, in the form of a large circle, a section of the earth through the magnetic meridian. On the circumference of this drawing, he next projected the dip of the needle in different latitudes from the equator to the pole, and by prolonging these projections until they meet in the interior of the earth, determining the position of the centres of magnetic influence in the two hemispheres. By this process, he arrived at the conclusion that the magnetic polarity of the earth is deeply seated in the interior, and that consequently the magnetism of the globe may be represented by a comparatively short magnet, the axis of which passes through the centre of the globe. A result similar to this was afterwards arrived at by a series of mathematical investigations by the celebrated Poisson. He also made a drawing of an arrangement of apparatus for obtaining an electrical spark from the magnetism of the earth. This consists in the rapid revolution of a large bar of soft iron on a horizontal axis at right angles to its length in the plane of the meridian, the bar being surrounded with a very long wire, insulated with a covering of silk; an arrangement being made to break the circuit at the instant of the bar receiving the greatest amount of magnetic induction. He succeeded by this arrangement in producing currents of electricity of considerable power, but for the want of a sufficient length, at the time, of insulated wire, he was unable to increase the intensity sufficiently to produce the spark, but that the result intended to be arrived at could be produced in this way there is no cause for doubt, provided the apparatus is constructed on a sufficient scale of magnitude.

I should have mentioned that Mr. Saxton constructed the apparatus by which Prof. Wheatstone made his celebrated experiment of measuring the velocity of electricity in its passage through a long wire. In this experiment the remarkable fact was discovered that in the discharge of a Leyden jar through a long wire the disturbance, whatever may be its nature, takes time for its propagation, and arrives last at the middle of the length of the conductor. On the cause of this phenomenon Mr. Saxton has some ingenious reflections.

While in London Mr. Saxton was elected a member of an experimental society, composed of men of scientific skill and mechanical ingenuity. It met once a week for the purpose of investigating certain classes of phenomena which did not require complex apparatus or long-continued observation. As an illustration of the character of this society, which might be adopted with advantage at the present day, I may be permitted to give an account of an investigation which it made of a phenomenon described by Sir D. Brewster in his work on Natural Magic, and which was said to have been exhibited in Italy by an officer in the American Navy. A man is laid on a table, face upward, with his arms crossed over his breast, and his whole body kept by sustained volition in a rigid condition; six other men then arrange themselves, three on each side, at nearly equal distances apart, so that two stand opposite each other at the shoulders, two opposite each other at the middle of the body, and the two others at the knees. Each of these then projecting the forefinger of each hand place it a little way under the body, and at a given signal, all, including the man on the table, inhale as full an inspiration of air as possible, and at another signal instantaneously and slowly breathe out the air over the recumbent subject, at the same time lifting gently, when the body will, according to the account, rise apparently without effort on the part of the lifters, and remain suspended for an instant on the ends of the fingers until the expiration of the air is completed. In the investigation of this phenomenon, as in that of all others, a director of the investigation was appointed whose instructions were implicitly followed. At the conclusion of a series of experiments the results were discussed, and any omissions that might have been observed were considered. If these were important the experiments were repeated, and so on until every doubt was removed, and unanimity of opinion obtained. In the case in question every member of the Society was at one time or another the load or a lifter, and particularly the heaviest and the lightest members were in succession placed upon the table. At the first trial some surprise was expressed at the apparently little effort required to elevate the body, and with the aid of a little imagination, persons not accustomed to scientific investigation might have thought that there was something mysterious in the result. But after full discussion it was concluded that the effect observed was due to the tension of the muscles of the body, the simultaneous effort of the lifters, and, above all, to the fact that the weight of an ordinary sized man, of say 150 pounds, when divided among six persons, or rather among twelve hands, would give to each hand only a little more than twelve pounds. But to bring this explanation to the test of experiment, a spring balance was attached to each forefinger of the lifters, and the amount of force thus exhibited being noted, the sum of the forces exerted was found exactly equal to that of the weight of the body lifted. The feat of supporting the weight of the smallest member after it had been elevated, for any length of time, upon the forefingers of six persons was found impossible.

In this Society Mr. Saxton, by his ingenuity in devising experiments, and his dexterity and skill of manipulation, was an active and important member.

He left London on the 1st of May, 1837, on his return to America, having been offered by Dr. Patterson, Director of the United States Mint in Philadelphia, the office of the constructor and curator of the standard weighing apparatus of that establishment. Previous to this, however, he had been tendered the office of director of the printing machinery of the Bank of England, but from undiminished attachment to his native country, notwithstanding nine years of absence, he declined the flattering proposition.

On the eve of his departure a farewell dinner was given him at the Piazzi Coffee House, at which were present some of the most prominent engineers and savants of the city. At the close of the banquet a work on mechanics was presented to him, by the editor, Jno. Isaac Hawkins, on the fly-leaf of which was the following inscription :—

"Presented April 26, 1837, by the Editor, to Joseph Saxton, Esq., of Philadelphia, at a farewell dinner given to him in London, previous to his departure for America, by eighteen of his friends, as a token of the high estimation in which they hold him as a mechanician of the first rank, and a man of science generally; in which estimation his fellow-citizen, the Editor, stands second to no one."

As a further illustration of the estimation in which he was held, I may quote, from a scientific journal[1] published at the time in London, the following extract :—

"Mr. Saxton, of Philadelphia, now in London, who is justly celebrated for his acute feeling in regard to the nature and value of accuracy in mechanism, and who is reputed not to be excelled by any man in Europe or America for exquisite nicety of workmanship, has made an instrument for cutting the teeth of watch wheels truly epicycloidal. Such an instrument ought to be in the hands of every engineer."

While in London, Mr. Saxton perfected the medal-ruling machine; an apparatus for tracing lines on metal or glass, at a minute distance from each other, which shall represent by an engraving the design on the face of the medal. A machine of this kind was invented in 1817 by Mr. Gobrecht, of the U. S. Mint, and applied to the engraving of medals. This was but the first step in the invention, the machine being applicable only to medals of low relief. It is not difficult to imagine an arrangement of machinery such that, while a blunt point, fastened at one end to a movable beam, in tracing a line across the face of a medal, rising and falling, according to the elevations and depressions over which it passes, another point connected with the same beam, shall draw a profile of this line on a flat surface. The simplest mode of effecting this would be that of placing the surface to be engraved at right angles to the plane of the medal. But the same can be effected, where the two surfaces are in one or in parallel planes, by a series of levers, which will convert the vertical into a horizontal motion. If now the tracer be made to

[1] Magazine of Popular Science, London, 1836.

move successively in a series of parallel lines at equal, minute distances over the whole surface of the medal, and at the same time the vertical motion is converted into one at right angles on the plate, a series of profiles will be engraved which together will form a picture of the medal. In this instrument, when the tracing point passes across any part of the medal in a straight line, a similar straight line will be etched or cut upon the plate; but when the tracing point rises above the base of the medal, the etching point will deviate from a straight line by a distance either equal to or proportional to the elevation. Two consequences follow from this effect. First, when the profiles of two consecutive lines passed over by the tracer are drawn on the plate, the more the second line rises above the first, the closer will the second line approach the first, and *vice versa*. Hence, the etching of that part of the medal along which the tracing point ascends in its successive passages will have its lines closer together; and that of the part along which the tracing point descends will have its lines further apart than those lines produced by the flat parts of the medal; and these crowdings and separatings of lines will produce shadings exhibiting a picture of the medal. But a second consequence of this arrangement is, that points which are in the same cross section of the medal are not represented in the corresponding cross line of the plate, but deviate from it in proportion as the path of the tracer is higher or lower. This gives rise to a distortion of the features, changing, for example, the relative position of the eye and the ear. This effect, though not very perceptible in copies of medals in low relief, becomes very objectionable in those of high relief. This defect, which was inherent in Mr. Gobrecht's instrument, was entirely remedied by Mr. Saxton. His improvement consisted in an ingenious contrivance by which the etching point was made to move over a distance equal to the horizontal projection of the tracing point in its up and down movements as it passes over the surface of the medal. For this purpose, the up or down movement of the tracing point must be to the movement of the etching point as the hypothenuse of a right-angled triangle to its base. And, furthermore, to effect this, he caused the tracing style to be inclined at an oblique angle to the plane of the plate, usually that of 45°. By these changes, requiring inventive powers of a high order, he removed entirely the distortion, and rendered the ruling-machine capable of engraving fac similes of medals, as well of high as of low relief. He subsequently rendered the apparatus entirely automatic by applying to it the motive power of water or steam, so that when once set in motion it would faithfully perform its task with unerring precision; and, when the ruling was completed, it would stop on the instant, cutting off the motive power. The rapidity of the execution was another feature of the apparatus; one face of a coin, an inch in diameter, ruled with lines the one two-hundredths of an inch apart, was completely engraved in about half an hour. The importance of this machine may be inferred from the fact that a new book of coins seems to be required by the commercial world about once in twenty years; and such a work is of comparatively little value unless fully illustrated by reliable engravings. A very interesting work prepared by Mr. Jacob R. Eckfeldt and William Du Bois, of the United States Mint, entitled "A Manual of Gold and Silver Coins of all Nations struck within the last Century," was published in 1842, and admirably illustrated by numerous engravings primarily executed by the apparatus we have just described. This work, which is well known to the professed numismatologist, should be in the hands of every one who desires to become acquainted with this branch of historic records. It is dedicated to Robert M. Patterson, M.D., Director of the Mint, and Vice-President of the Philosophical Society; a gentleman who was no less remarkable for his varied and profound scientific acquirements than for kindness of heart and urbanity of deportment. He was a warm admirer and ardent friend of our lamented associate; and it was he who, as we have said before, recalled Mr. Saxton from London and gave him the position of balance-maker to the Mint of the United States.

Dr. Patterson was fond of exhibiting and explaining Saxton's ruling machine to the distinguished visitors of the mint. It was, indeed, an interesting exhibition to see this machine engraving its fine lines, moving its tracer backward and forward, without the aid, or even the observation, of a superintendent, and stopping when its task was accomplished, and, by the sound of a bell, calling for more work.

"I recollect," says a friend, when the President of the United States and his cabinet were making a visit to the mint, the pleasure manifested by Dr. Patterson in showing the machine in operation. They all appeared deeply interested in the exhibition, with the exception of the Secretary of the Treasury, who, when told that it was not making, but copying coins, turned upon his heels without giving it further attention, disappointed, it would seem, in its not being able to contribute to the material of his department."

Mr. Saxton constructed during his connection with the mint, the large standard balances still used in the annual inspection of the assays and the verification of the standard weights for all the government assay and coining offices in the United States. The knife edges of these implements are of the hardest steel, turning upon plates of agate, and such sensibility has the apparatus, that when loaded with fifty pounds it turns with one-tenth of a grain, or, in other words, with the three-millionth part of its load.

Mr. Saxton was elected a member of the American Philosophical Society in 1837, and renewed his association with the Franklin Institute. In November, 1834, he was awarded the Scott legacy medal of the latter establishment, for the invention of a reflecting pyrometer, in regard to which the following is the report of the committee to which the invention was referred.

"This instrument shows and measures, in a peculiar and advantageous manner, the linear expansion of a metallic or other rod subjected to the influence of heat. The rod resting against a fixed support at one end, the other end of it presses against a sliding bar, which carries an arm attached to one end of a fusee chain of a watch. This chain is wound around an axle carrying a mirror; and the other end of the chain is fastened to a spring, to preserve its tension. Hence as the rod under trial expands, and the sliding bar moves, the axle and mirror revolve, and if a sunbeam thrown upon this mirror in a proper position, be reflected from it upon a distant wall, the angular motion of the reflected image will be twice that of the axle; and will serve to measure the amount of expansion. As the sun is also in motion, a fixed mirror near the revolving one is made to reflect another beam, at first coinciding with the former one; and as the latter beam moves only with the sun, the angular distance between the two reflected beams or images will be twice the angular motion of the axle. This instrument is especially valuable for the trial of compensating pendulums, as has been proved by Mr. Saxton.

For this purpose, the pendulum was inclosed in a hollow cylinder, in order that hot or cold water might be used for varying the temperature, the cylinder was supported vertically in a proper wooden frame; and the lower end of the pendulum, passing through a cock tightly closing the lower end of the cylinder, was adjusted to the sliding bar beneath it, which pressed firmly upward against the pendulum by the action of a spring. By this arrangement the revolving mirror was found always to return to its first position, when slightly moved by the hand; thus showing the delicacy of the mechanism, and the pendulum was considered perfect when a change of its temperature caused no motion of the revolving mirror.

"The Committee deem this invention of Mr. Saxton's so useful and ingenious that they recommend the award of a Scott's legacy medal as a slight recognition of his service in the cause of science and the useful arts."

Professor Mayer of Stevens Institute, one of our fellow-members, informs me that he used Mr. Saxton's comparator in an elaborate research on the effects of magnetism in changing the dimensions of iron, and found it to exceed in minute precision all other instruments, indicating changes in the length of a bar to the $\frac{1}{100000}$th part of an inch.

On the death of Mr. Hassler, superintendent of the Coast Survey, in Nov. 1843, Prof. Alex. Dallas Bache was called to fill the important sphere of duty thus rendered vacant. The office included also the superintendence of the weights and measures of the Government, and immediately after his appointment he tendered to his friend Mr. Saxton the charge of the construction of the standard balances, weights, and measures to be presented to each of the States for insuring uniformity of measures in all parts of the country. Mr. Saxton accepted this position, and immediately removed to Washington, where he was destined to spend the remainder of his days. His labors, however, were not confined in this new position to the construction of the weights and measures, but were extended to the construction of different portions of the complex apparatus employed in the varied and multiform operations of the Coast Survey. In this connection he invented an automatic instrument for recording the height of the tides, corresponding to the different hours of the day. He also applied his reflecting pyrometer to the construction of measuring rods which would retain their unvarying length while subjected to different temperatures. These rods were used with great success in measuring the base lines and lines of verification of the survey, an operation which was performed with such accuracy with the aid of Mr. Saxton's improvements that with repeated measurements under different temperatures in a distance of five miles, a difference would be found not to exceed one-half inch.

Among other improvements made by Mr. Saxton in the apparatus used by the Coast Survey, was that of rendering automatic the large dividing machine for graduating the limbs of angular instruments. By this improvement the heat of the body was removed, and all irregularity occasioned by personal peculiarities, such as tremor of hand, defect of vision, etc., was obviated. The drawings of the proposed improvement were made by Mr. Saxton and the work executed by Mr. Wurdemann, the mechanician of the Coast Survey. The machinery is too complicated to be understood without a drawing. The power to give motion to the apparatus was drawn from the water supply of the building, and applied directly to a small turbine wheel of a few inches in diameter, the induction tube of which, connected with the supply pipe of the house, was of India rubber of about three-quarters of an inch in diameter; the eduction tube was of the same material and of the same diameter, passing down through the floor, discharging the water into the drain beneath the house. By this arrangement, though the motive power was water, yet none of the liquid was observed in the room in which the apparatus was situated. The work required to be done by this turbine wheel, the power of which was transmitted by a pulley and cord to a large wheel turning an axis tangent to the large divided circle, was first to move this circle through one division and with it through an equal angular space, the smaller circle which was to be divided. The large circle stopped at this point until a small lever bearing the marker on one of its ends rose above the circle to be divided, moved to its outer circumference, then toward the centre of the circle across the limb, making a permanent cut, then stopping and remaining stationary until the two circles had made another movement equal to a given division, and the above mentioned process repeated. These automatic movements were effected by an arrangement of cams which converted the rotatory into horizontal and vertical motions. The effect on the observer was that of a series of movements produced by human volition. The results, however, were very different, since, however admirably adapted the human machine may be to execute the intentions of the will, yet the will itself is inconstant, the attention soon becomes fatigued, and the application of thought to one unvaried process of acts soon becomes unsteady. In the case of the machine, however, there was no effect analogous to fatigue, no thought was required to direct at every instant the motion, and the pen or marker at the extreme point, impelled by a train of mechanism, pursued unchangeably its predestined course.

At the meeting of the American Association in Baltimore in 1858, Mr. Saxton gave an account of the principal applications which he had made of the revolving mirror to minute measurements in addition to the pyrometer previously described. In the application of this principle to the adjustment of the measuring rods of the Coast Survey, and for minute measurements, he had applied, instead of a sunbeam, a graduated scale, the reflection of which entered the object glass of a telescope and was then observed highly magnified. With this improvement an elongation which does not exceed the one hundred thousandth part of an inch becomes a very distinct and measurable magnitude. The same apparatus was applied at the request of Capt. (now General) Meigs to determine the expansion of different specimens of marble cut into prisms of the same length and cross section, to ascertain the relative thermal expansion. The same principle is evidently applicable to all cases where the measure of changes of length or of angle or position is required. It was applied by Mr. Saxton in the Girard College Magnetic Observatory, to indicate changes of magnetic dip and also to magnify the motion of the axis of an aneroid barometer. For this latter purpose the case of the instrument is removed and a mirror of about one-half an inch square is attached to the first axis of motion. The aneroid thus furnished is fastened to a bracket on the wall with the axis to which the mirror is attached placed horizontally. At the distance of about fifteen feet from the mirror a telescope is permanently adjusted, so that the image of a divided scale placed immediately below the object glass can be seen in the mirror. With this arrangement, the slightest change in the pressure of the air became apparent. The opening or closing of a door, or a gust of wind over the house, produced marked disturbances in the pressure of the atmospheric column, the extent of which could be readily measured.

The application by Gauss of the mirror to a magnetic bar to magnify its angular variation was subsequent to its first use for a similar purpose by Mr. Saxton. The first application by our associate, of the principle of the turning mirror to magnify angular motion was as early as 1825. One of his modifications of the revolving mirror consisted in fastening obliquely to a revolving axis, a small mirror on which, if a ray of light was thrown from any source and when a sufficient velocity was given to the mirror, a large circle of light would be projected on a prepared screen or on the ceiling of a room. A rapid revolution was given to the axis by a train of wheels driven by a coiled spring, and with this instrument rapid fluctuations in the intensity of a light could readily be observed. When the ray of light was from charcoal points, forming the poles of a galvanic battery, the circle of light exhibited a mottled or dotted appearance, indicating a rapid alternation of intensity in the electrical discharge.

Among the inventions which he made after his return to America, was that of a stove for burning anthracite coal. In this, the draft was regulated by the different expansion of two metals, by which a valve was opened or closed to the required extent for preserving the stove at a given equable temperature, which could be regulated in advance.

Another invention was that of a method of sealing official papers by means of a fusible metal, obviating the necessity of the use of wax, which is found to melt in passing through the mail in warm countries. The same contrivance is used for fastening trade marks on goods.

He also made a hydrometer, by which the quantity of spirits in a mixture was immediately indicated by the number of links of a fine chain, hanging from the lower part of a floating bulb, and partly resting on the bottom of the vessel. When the strength of the liquor was diminished by the addition of water, the bulb would float higher, drawing up from the bottom an additional number of links, until the equilibrium was again obtained.

It would appear from the facts relative to the life of Mr. Saxton, that he devoted himself to invention more from the mental pleasure which he derived from this exercise of his imagination, than from any desire for scientific reputation or for pecuniary gain. We have seen that he published no account of his magneto-electrical machine until he was called upon to defend his claim to the invention, though it was publicly exhibited in the Adelaide Gallery for months, and had excited the admiration of the many visitors to that establishment; and that although several of his inventions were patented in London, this was through the influence of others, who desired to share in the profits, rather than by his own act. Had he secured the exclusive right to manufacture the metallic cartridges, of which he was undoubtedly the first inventor, he might have acquired wealth sufficient to realize the dreams of avarice. The pleasure of exercising his inventive powers, and the gratification of employing the products of his ingenuity, were enough for him; and with the characteristic of unselfish genius, he left to others to gather the golden apples which he strewed along his path.

Mr. Saxton was not a mere practical man in the ordinary sense of the term—that is, one who by repetition and empirical imitation, becomes expert in the performance of operations devised by others, and has no knowledge of principles. On the contrary, he had clear and definite conceptions of the scientific elements of physical energy in its multiform manifestations, and, with an ever-teeming imagination applied them with success. He was singularly free from unconditioned speculations, and although he possessed an imagination of great fertility, it was always under the control of a discriminating judgment which confined its operation to the region of the tangible and the actual.

Such was his habit in the exercise of his invention that he could scarcely be prevailed upon to reduce to practice the conceptions of others, or if at any time in the course of his official duties he was called upon to perform a work of this kind, it was always executed with modifications of his own.

Mr. Saxton was at no period of his life a profound student of science. He possessed more wisdom than learning; after having obtained a clear and distinct conception of a general principle he reflected deeply on this, deduced logical consequences from it; imagined new conditions, and inferred new results. I doubt whether at school he was considered a bright youth, possessing the faculty of rapid acquisition. This faculty and that of original conception are not always found in the same individual; so far from this being the case, the contrary is the rule and the other the exception. No amount of drilling can make, for example, a first-class engineer if the proper constitution of mind be wanting. A pupil may in after life disappoint the expectations of his friends on account of the promise founded on an aptitude for acquiring expertness in mental operations and a knowledge of rules, without a definite conception of principles.

Mr. Saxton, in person, was considerably above the ordinary height, and admirably proportioned. He had a broad and high forehead, a countenance marked by thought and benevolence. He delighted, as we have said, in hunting and fishing, and in making excursions on the water or in the woods in the vicinity of Washington. While he was thus exercising his body, his mind was actively employed; nothing appeared to escape his attention. He made a large collection of pre-historic implements to be found in the vicinity of Washington, and collected specimens of the geology and mineralogy of the District of Columbia. He was of singularly modest deportment, and only in the company of a few persons, and those his intimate acquaintances, did he give indications of his intellectual powers.

In 1850 Mr. Saxton married Miss Mary H. Abercrombie, the granddaughter of a well-known Episcopal clergyman of Philadelphia, and although there existed between himself and his wife a considerable disparity of age, the union was a fortunate one. His wife sympathized in his pursuits and affectionately administered to his wants in his declining health. The issue of this union was a daughter, now the wife of Lieut. Pendleton of the U. S. Navy.

Within a few hours of the death of our associate his daughter gave birth to a son, who having received the name of Joseph Saxton, we may hope that he possesses the germs of the mental and moral peculiarities of his grandsire, and will thus not only transmit his name to posterity, but also peculiarities which will affect for good coming generations.

About fifteen years before his death he was suddenly seized with a partial paralysis from which he never entirely recovered. Another attack followed about ten years later, and after lingering for two years or more, his power of utterance gradually diminishing, he became incapable of articulation, and finally, before breathing his last, became unable to hold communication with the external world. His end, however, was peaceful, and he received from his affectionate wife and daughter all the vigilant care and tender sympathy which fervent devotion could contribute.

I trust, in what I have narrated relative to the life and labor of our deceased companion, that he will be deemed worthy of having been a member of the National Academy of Sciences.

MEMOIR

OF

HENRY JAMES CLARK.

1826–1873.

BY

A. S. PACKARD, Jr.

Read before the National Academy, April 23, 1874.

BIOGRAPHICAL MEMOIR OF HENRY JAMES CLARK.

MR. PRESIDENT AND GENTLEMEN:

Within the year past we have lost a member who may be said, without disparagement to others laboring in the same field, to have been the foremost American histologist and microscopist, and one of our most skilful and accomplished biologists; one the rule of whose scientific life was a practical application of experimental philosophy. A true naturalist, he was an enthusiast, and yet in his methods of study severe, exact, and in all respects scholarly.

HENRY JAMES CLARK was born June 22, 1826, at Easton, Massachusetts. Of his early life little information has been obtained except that he was fond of drawing, an art which proved of much service and credit to him in after years.

He received his collegiate education at the University of the City of New York, graduating in 1848.

His first love for science seems to have grown from his fondness for flowers. At what age this was manifested we do not know, but that it must have been a passion, one determining the bent of his life at the time of his graduation, seems more than probable. Immediately after leaving college he taught for some time at White Plains, New York. While there, in some of his out-of-door rambles—and he was fond of taking long walks—he found a flower which he thought was new. On returning home he ascertained that it was not described in Professor Gray's Botany. He at once began a correspondence with Professor Gray in regard to it, and eventually received an invitation from him to go to Cambridge. He went there as a student of botany under Professor Gray in 1850, and this may be regarded as the date of his scientific birth. While a student at the Botanic Garden, he taught the academy at Westfield, Massachusetts, for a single term, apparently achieving much success as a teacher, and forming life-long friendships.

Soon after this he became a student of Professor Agassiz; but his love for botany never diminished. He studied it in after years from the side of vegetable histology and morphology in connection with and as illustrating the histology and morphology of animals. The influence of his knowledge of botany on his zoological studies was marked. It prepared him for his studies on spontaneous generation, on the theory of the cell, on the structure of the Protozoa and the nature of protoplasm. In studying the lasso-cells of the Acalephs, he traced their analogical resemblance to the stinging hairs of the nettle. By his intimate knowledge of the spores of the smaller Algæ he was able to point out some of the characters separating the lowest Protozoa from the spores of plants, and aid in the work of Thuret and others in eliminating from the animal kingdom certain vegetable spores which had been originally described as infusoria.

His first scientific paper was on a botanical subject, "The peculiar growth of rings in the trunk of *Rhus toxicodendron*," published in 1856, and this was supplemented by unpublished studies on the eccentricity of the pith in *Ampelopsis quinquefolia* and *Celastrus scandens*. He made experiments for a series of years on the value of the bark to the life of the tree. He also studied certain morphological points. As an example, he observed the relation and development of the filaments which connect the anthers to the sepals of *Comandra umbellata*. In his paper on the origin of Vibrio (1859), he showed how the fibrillæ of the muscles during decomposition break up transversely, the fragments assuming the form and movements of Vibrios. He also made observations on the absorption of albumen in the cells of plants. His second purely botanical paper, and the last he published, was on the nature of the glandular dots of the Pine (1859). His skill in the use of the fine lenses made by Spencer, of Canastota, New York, enabled him to see more than his predecessors of the true relations of these dots. But that his botanical studies did not end here may be seen by reference to his diaries, and his frequent allusions to the lower Algæ and to vegetable histology in his "Mind in Nature." In his walks he often botanized, and contributed in this way to Gray's botanical text-books. Thus with the training he received from Professors Gray and Agassiz, he looked upon the world of organized beings from both the botanical and zoological side. He well deserves the name, *biologist.*

He graduated from the Lawrence Scientific School in 1854, taking the degree of B.S. He was for several years the private assistant of Professor Agassiz, who early in 1857 spoke of him enthusiastically, remarking to a friend, "Clark has become the most accurate observer in the country." On Sept. 29, 1854, he was married to Mary Young Holbrook of Boston. They had eight children, of whom seven are living. Between 1856 and 1863 he was associated with Agassiz in the preparation of the anatomical and embryological portions of the "Contributions to the Natural History of the United States." Here his great skill and delicacy in the use of the scalpel and pencil won much praise from naturalists. Nearly all the plates in the Contributions illustrating the embryology and histology of the turtles and Acalephs are signed with his name. The drawings were not only beautifully worked up, but possessed the merit of extreme accuracy.

In the use of the microscope, Clark showed not only mechanical skill and ingenuity, but a patience, caution, and experience in difficult points in histology, which undoubtedly placed him at the head of observers in this country, and rendered him perhaps inferior to few in Europe. He used the highest powers with a skill that few if any living observers have surpassed. He suggested improvements, carried out by Spencer, at the instance of Professor Agassiz, in this instrument. The first great microscope made in Germany was constructed in 1829 by Fraunhofer for Professor Agassiz. A second, and one pronounced by Clark as not surpassed "in all Germany to this very day" (1859), was made by Oberhäuser in 1832. In 1857, Professor Agassiz sent Clark to Canastota to confer with Spencer, and as the result, a microscope was made by Spencer which was fully equal to any made at that time in Europe. Clark suggested that we must have three kinds of objectives: one with the field extremely flat; another, an immersion lens—the first made, so far as we are aware, and now so universally used;—and a "third with a depthing focus extending as far as possible beyond that of the ordinary kind, for the purpose of viewing objects as a whole, in order to ascertain the relations of their different parts." This microscope was in use in 1859. It should be observed that Clark's high opinion of Spencer's objectives was formed, to use his own language, "after having tested from time to time some of the best English microscopes which have been made since the 'Great Exhibition,'" and "therefore I am not to be supposed to have made so great a leap as if from an Oberhäuser to a Spencer." He insists on the value of a flat field and wide angular aperture, and at the present day, fifteen years later, lenses are made with still lower angles of aperture than in 1859 for histological studies. During this time Clark began the serious study of the Protozoa, undoubtedly compelled to do so in order to properly interpret the histological facts then accumulating in the study of the Radiates. After leaving Cambridge he studied the Infusoria and lower plants, and made drawings and notes, comprising descriptions of many new forms of Infusoria. He planned an extensive work upon this subject, portions of which are now in charge of the Boston Society of Natural History for publication. The drawings are of great delicacy and beauty, and, had he lived to complete the work, it would doubtless have been equal to if not in advance of Claparède and Lachman's famous work on the Infusoria. He did not dissociate the Protophyta from the Protozoa, regarding them as almost inseparable in nature; thus, as we have ascertained in his lectures to his classes, well nigh anticipating Haeckel's classification of the lowest forms of the animal and vegetable kingdom into the Protista and Protozoa.

His assiduous, confining labors seriously injured his health. His constitution was not strong. Already, in 1857, we find entries in his diary of symptoms indicating that the seeds of the disease that was to carry him prematurely off were then sown. He was not even then robust, and his life ever after was a struggle with disease, and the cares of a large and increasing family.

In June, 1860, he was appointed adjunct Professor of Zoölogy in the Lawrence Scientific School, which he held until the expiration of his term of office; and, in the spring and summer of 1861, gave a course of lectures on histology at the Museum of Comparative Zoölogy. In the spring of 1863 arose a sudden and unfortunate disagreement with Professor Agassiz, which led to the termination of his connection with the Museum of Comparative Zoölogy. In the spring of 1864 he delivered a course of twelve lectures at the Lowell Institute in Boston, which were published in the same year, under the title of "Mind in Nature;

or, the Origin of Life, and the Mode of Development of Animals." This is in all respects, for its usually sound and clear thinking, its breadth of view, and the amount of original work it contains, perhaps the most remarkable general zoölogical work as yet produced in this country. If the author had left us no other work, this alone would testify to years of the severest labor and independent thought. It anticipated certain points in histology, and the structure of the Protozoa and Sponges especially, which have made the succeeding labors of some European observers notable. It is a most readable book, although the style lacks that elegance and attractiveness which distinguish some of the popular works on science of the present day.

Professor Clark adopted and strongly urged the doctrine of spontaneous generation, from the facts afforded by the experiments of Professor Wyman, and on the question of evolution adopted views resembling those of Professor Owen. The original matter in the book is that relating to the structure of *Bacterium termo*, and *Vibrio baccillus*, the theory of the egg and its polarity and bilaterality, and the cellular structure of Actinophrys, with many other new points relating to the anatomy and physiology of the Protozoa and Radiates. The new discoveries and inductions give a special value to the work, and afford evidence of the scholarly and thoughtful mind of their author. Few are the facts gleaned from other authors which he did not verify, and so fresh and suggestive is the mode of treatment, and conscientious the spirit of the book, that it will, if we mistake not, remain a classic. Certainly there is no work in the English language that covers the field it occupies.

The remaining events in the life of our friend and associate may be, alas, too briefly related. In December, 1866, he was appointed Professor of Botany, Zoology, and Geology in the Agricultural College of Pennsylvania. He resided at Centre County, Pennsylvania, the seat of the College, until April, 1869, when he was appointed to the Chair of Natural History of the University of Kentucky. He lived at Lexington, Kentucky, until February, 1872, when he was elected Professor of Veterinary Science in the Massachusetts Agricultural College.

During this period he suffered much from sickness; still he managed in intervals of college duties to produce some remarkable memoirs. In his first paper on Actinophrys (1863), he discovered that "all vibratile cilia originate in the amorphous intercellular substance," and do not form direct prolongations of cells. In 1864 appeared a brief paper in which he showed that Tubularia was not parthenogenous, having found, by the aid of Tolles' improved quarter of an inch objectives, that it produced eggs. Perhaps the most important work he has done is in his studies on the affinities of the sponges. In November, 1866, appeared, in the American Journal of Science and Arts, a brief paper, entitled "Conclusive Proofs of the Animality of the Ciliate Sponges, and of their Affinities with the Infusoria Flagellata." While he had in his Lowell Lectures endeavored to show that there was a unity of plan in the organization of the Protozoa, their bodies being arranged in the form of a helix, he now endeavored to show that the sponge did not depart from the protozoan type. By the discovery of a remarkable form (Codosiga) he was enabled in it to trace a link, in his opinion, uniting the sponges with the flagellate Infusoria, such as Monas, Anthophysa, and Codosiga. In the full memoir, which was published a year after, with numerous figures, under the title "Spongiæ Ciliatæ as Infusoria Flagellata," he attempted to establish the homology of the flagellate cells, constituting the tissues of the sponge, with the flagellate Infusoria. He demonstrated, by the use of the superior objectives made by Tolles, that these cells are like Monads, with contractile vesicles, nuclei, a collar, and flagellum; that the sponge was in fact a compound monad, and not a compound amœba, as insisted on by Carter in 1854–57, and Lieberkuhn in 1856 and 1857. This was a great step in advance of previous observers. Certainly an organism with cells so highly differentiated as those in the sponge cannot be a plant, and while, as Clark observes, Carter had "been the first to present anything like decisive proofs of the animality of the sponges," yet this was confirmed and demonstrated still more completely by Clark himself. In this memoir he insists upon the fact that these simple "monas-like infusoria," making up the compound body of the sponge, were undoubtedly endowed with a distinct mouth, afterwards in 1871, distinctly seen; while Carter described them as engulfing food like an amœba, any part of the cell acting as a mouth. Of course it is necessary for our author to prove that Monas is an animal. This he does conclusively, showing it has a distinct mouth, with a "lip," into which food is thrown by the flagellum. The cells or zoöids of the sponge (*Leucosolenia*) agree with Monas in all respects except that he did not detect the mouth, though he saw currents of floating particles which "are constantly whirled in by the flagella and made to impinge upon the area within the collar."

The study of the sponges has since the publication of this important memoir been pursued by Oscar Schmidt, Miklucho Macleay, and Ernst Haeckel. Considerable advance has been made regarding the organization of the adult, while the young of the sponge has been proved to be like the planula of a radiate, and made up of two layers of cells. Haeckel afterwards assumed, and proved, we think, that Clark was wrong in regarding the sponge as a compound Flagellata Infusorian, considering Clark's monads as simple ciliated cells, provided with a collar. Inasmuch as the sponge, then, is made up of two layers of cells, it is not a Protozoan, but, in Haeckel's view, homologous with the Radiata, among which he, in accordance with Leuckart's views published in 1848, consequently places them.

The last paper he published was entitled, "The American Spongilla, a Craspedote, Flagellate Infusorian," in which he criticizes Haeckel's views on the affinities of these animals, and insists upon their affinities to known Flagellate Infusoria. This was published in December, 1871, in the American Journal of Science and Arts. An extended memoir on Lucernaria is now being published in the Smithsonian Contributions.[1]

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[1] One of the memoirs accepted for future publication in the Contributions is on Lucernaria, by Professor Henry J. Clark. His work is divided into two parts; the first devoted to the "general and comparative morphology," and the second restricted to the "anatomy and physiology of *Haliclystus auricula*." In the first part are three chapters; the first on "individuality," in which are considered the questions relating to "polarity and polycephalism," and "the hydroid and medusoid cephalisms." In the second, the thesis that "the type of form is not radiate" is defended, and the form is described as "the dorso-ventrally repetitive type." The third chapter is devoted to the consideration of "antero-posterior (cephalo-caudal) repetition," and under the heads of "the scyphostoma and ephyra varieties of the same morph" and "the individuality of Pelagia and Lucernariæ."

In the second part are four chapters, the third to seventh of the entire work. In the first (third of the work) are described the "general form and structure," including habitat, habits, form, and size, the proboscis, Busy with his work at Amherst, and struggling with the fatal disease (tabes mesenterica) which was rapidly reducing his bodily strength, he wasted away, and died on the first day of July, 1873, in full possession of his mental faculties. He left a wife, seven surviving children, and many warm friends to mourn his loss.

He was a man of the warmest sympathies, a devoted and affectionate husband, a loving brother, and dutiful son; in many respects an admirable teacher, as a lecturer clear and systematic, with an enthusiasm that evinced the true naturalist. The secret of his success as an investigator may be stated in his own words taken from his diary, where he says he made it a rule to practise the "utmost rigidity and thoroughness in his researches, without regard to time consumed or the value of the results." He had the best of teachers, and he made the most of his opportunities. We may look upon the results of his work as elevating the standard of American scientific work.

He was a member of most of the learned societies in this country, while his works have been recognized and referred to by some of the leading zoölogists in Europe.

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the umbella, and the peduncle. In the second is considered the "organography, including the walls," "the muscular system," "the tentacles, the marginal adhesive bodies, or colletocystophora," "the caudal adherent disk," "the digitiform bodies, or digitali," "the digestive system," "the nervous system," and "the reproductive system."

In a third are embraced the results of studies of the "embryology," or various stages of growth of the species, including observations on "the egg and the spermatozoa;" on "a young *Haliclystus auricula*, nearly one-sixteenth of an inch in diameter;" on "a specimen three thirty-seconds of an inch across the umbella;" on "a young specimen one-eighth of an inch across;" on the "special development of a tentacle, a colletocystophore, and a genital sac;" on the "young one-fifth of an inch across;" and on the "young six twenty-fifths of an inch across."

In a fourth chapter the tissues are considered in an "histology of *Haliclystus auricula*," and in the several parts of the body—that is, "the umbellar and peduncular walls;" "histology of the tentacles;" "histology of the colletocystophores" (anchors); "histology of the caudal disk;" and "histology of the digitali" and "the prehensile cysts" (nematocysts and colletocysts).—*Report of the Board of Regents of the Smithsonian Institution for* 1873. Washington, 1874.

HENRY JAMES CLARK.

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MEMOIR

OF

JOSEPH WINLOCK.

1826–1875.

BY

JOSEPH LOVERING.

READ BEFORE THE NATIONAL ACADEMY, APRIL 19, 1876.

BIOGRAPHICAL MEMOIR OF JOSEPH WINLOCK.

PROFESSOR JOSEPH WINLOCK was born in Shelby County, Kentucky, on February 6, 1826. He died, suddenly, at Cambridge, Mass., in all the strength of his manhood, and at the height of his usefulness, on June 11, 1875. The day before that of his death, he was at his usual work, with no warning of his impending fate except from a sense of increasing lassitude which he had felt for several weeks.

His grandfather, a Virginian by birth, was General Joseph Winlock, who joined the American army, at the outbreak of the Revolution, when he was only eighteen years of age. He served at first as a private, and was afterwards promoted to the rank of ensign, lieutenant, and captain. He was engaged in the battles of Germantown, Brandywine, Monmouth, etc., and was with Washington at Valley Forge. In 1787, he married Miss Stephenson of Virginia, and settled in Kentucky, where he was employed in surveying and entering land. He was sent to the Convention which framed the Constitution of Kentucky, and, afterwards, for some years to the State Senate. He commanded the troops of the State which were ordered out to intercept the expedition of Aaron Burr in 1806. In the war of 1812, he held the rank of Brigadier-General, and went with three regiments to Vincennes.

His son, Fielding Winlock, the father of Professor Winlock, was born in Kentucky on May 4, 1787. He studied law, at first in the office of Felix Grundy, and, after Mr. Grundy's removal to Nashville, in the office of Henry Clay. During the preparations for the War of 1812, he was clerk of the committee of the State Senate on military affairs, performing also many of the duties of Adjutant-General. He left this position to serve in the army as aid to his father, and, in the campaign which ended with the defeat of Proctor and Tecumseh, on General Shelby's staff. After the war he held, at different times, various places of honor and trust, and died at the advanced age of eighty-five.

Professor Winlock was educated at Shelby College, Kentucky, where he graduated in 1845. At this early age his tastes and acquirements were conspicuous; and he received immediately the appointment of Professor of Mathematics and Astronomy in that institution. He devoted his first savings to the purchase of a set of the *Astronomische Nachrichten;* and, in order to be able to read it, he rose early in the morning to talk German with a rude laborer upon his father's farm, before the day's work began. Fortunately for himself and for science, he attended the fifth meeting of the American Association for the Advancement of Science, which was held at Cincinnati in the spring of 1851. It is not among the least of the advantages of this association that it brings into notice young men of promise who might otherwise live and die in obscurity, revealing to themselves as well as to others, by comparison, their rare intellectual endowments. In this case, the chief of American mathematicians recognized, in the Kentucky professor, one who had mastered and enjoyed his own highly condensed treatises, however distasteful they may have been to commonplace students and teachers. This happy conjunction of kindred minds resulted in bringing Mr. Winlock to Cambridge in 1852. Cambridge was, at that time, the headquarters of the American Ephemeris and Nautical Almanac; a great work, ordered by Congress in the Act of March 3, 1849, and placed under the superintendence of Lieutenant (now Admiral) C. H. Davis. Mr. Winlock joined the able corps of computers, on whose ability and fidelity the life of the Almanac depended, and remained in this service until 1857, when he was appointed Professor of Mathematics in the United States Naval Observatory at Washington. He had been in this new position for only a short time when he was made Superintendent of the Ephemeris and Almanac, and returned to Cambridge.

He vacated this post in 1859, and removed to Annapolis, where he had charge of the mathematical department in the United States Naval Academy. Soon after the removal of the Academy to Newport, in consequence of the war of secession, he was again made Superintendent of the Ephemeris and Almanac, and lived in Cambridge. During his long though interrupted connection with this national work, which has contributed largely to the cultivation as well as to the credit of mathematics and astronomy in this country, he made many valuable contributions to it, among which that of his carefully prepared Tables of Mercury was the most important.

In 1866, with no effort on his part, he received the appointment of Phillips Professor of Astronomy in Harvard College, and Director of the Observatory. To his titles was afterwards added that of Professor of Geodesy in the Lawrence and Mining Schools of the College. While he was Professor at Shelby College, he had made himself familiar with the construction and manipulation of the equatorial telescope. An excellent Merz instrument of this description, having a focal length of 9½ feet and an aperture of 7½ inches, was the property of that institution, and was afterwards borrowed by Mr. Winlock, and mounted at Cambridge, for a time, for his private use. With this exception, his scientific labors had been exclusively in the way of the higher mathematics, either as teacher or computer. It was not until he was relieved from the work of routine, and became Director of the Observatory at Harvard College, that he had an opportunity to develop and manifest his remarkable mechanical ingenuity and genius for invention. An ample and deserved tribute is paid to the memory and the services of the two lamented Bonds (the father and the son), when it is remembered that their lives, consecrated to astronomy, founded the Observatory, and won for it the sympathy and support of the community. Affection for them, and respect for their disinterested zeal, inspired the liberal endowments which strengthened its early growth. Because the men were there, the institution was born and lived. The buildings and equipments of the Observatory, under its first directors, put to shame many similar establishments in Europe. The possession of a magnificent refractor, equatorially mounted, approached by a skilfully devised observer's chair, and accommodated under an immense dome which was moved with marvellous ease, contrasted favorably with deficiencies in instruments and machinery at older observatories, and gave to the one at Cambridge, at once, a name and a rank among the best in the world. With delicacy and disinterestedness of feeling, eminently characteristic of Mr. Winlock, his first thought, on assuming the duties of Director, was for the reputation of his predecessors, with which the reputation of the Observatory was intimately associated. As rapidly as the resources of the Observatory permitted, he provided for the reduction and publication of their unfinished work. Thus the Annals of the Observatory have been enriched by a volume on Sun-Spots, and others on a catalogue of Zone-Stars. Another is yet to appear containing a catalogue of Polar and Clock Stars.

But it was impossible for the Observatory to maintain its high standing and remain stationary, while the old observatories elsewhere were remodelled, refurnished, and prepared to start upon a new career; and young observatories, richly appointed, were springing up in both hemispheres. The inventory of instruments, at the disposal of the Bonds, comprised the large equatorial, a five-foot equatorial, a four-foot transit-circle, a Bond clock and chronograph, two chronometers, and a set of Lloyd magnetometers for obtaining the elements of the earth's magnetism. During the nine years of Mr. Winlock's vigorous administration, the instrumental appliances of the Observatory were strengthened in all directions. A seven-foot equatorial by Clark, another Bond chronograph, a Bond standard-clock with break-circuit attachment for transmitting time-signals, a Frodsham sidereal clock, a Frodsham *break-circuit* sidereal chronometer (the original device of Mr. Winlock), a mean-time chronometer, a thermometric chronometer, a photographic telescope of long focus, a Russian transit, made in the workshop of the Pulkowa Observatory, a Zöllner astrophotometer, a large Ruhmkorff coil, various spectroscopes and self-recording meteorological instruments; all this rapid increase of resources, while it added to the power, greatly multiplied the responsibilities of the Director. The costly transit-circle, though constructed upon the best models and by the most excellent artists, had always proved a failure and a disappointment; as Mr. Bond supposed, from fatal injuries which it received in its transportation. Though it was useful as a transit-instrument, implicit reliance could not be placed in it as a circle. The consequence was, that the great equatorial was too frequently called away from its legitimate work to do the duties which belonged properly to the circle. Mr. Winlock was not long in inspiring the friends of the Observatory with that large measure of confidence in his capacities and his sound judgment which prompted them to contribute over $12,000 for the purchase of a new meridian circle. In the autumn of 1867, Mr. Winlock went to Europe, and spent four months in visiting the principal observatories, and acquainting himself with the latest improvements in instruments, and especially in circles. Having studied the advantages and the defects in the highest class of meridian instruments, he blindly copied no one of them; but suggested valuable modifications, with the view of securing greater stability, increased precision of movement, and the most complete facility of observation. The improvements which he suggested were warmly approved and promptly adopted by the artists whom he preferred, Troughton and Simms of London; his modifications of the old construction have been fully justified by the results since the new circle has been put to work, and other astronomers have given the best indorsement by copying them. The eminent astronomer and mathematician, J. C. Adams, now President of the Royal Astronomical Society, ordered a circle from the same artists and of the same pattern for Cambridge, in England. In November, 1870, when the new instrument was ready for use, Mr. Winlock turned it upon the zone of stars between 50° and 55° of north declination. When the whole field of observation was divided between the different members of the *Astronomische Gesellschaft*, this was the share which fell to the Observatory of Harvard College. Already 15,000 observations have been made upon the zone-stars, and in two years more the great work will be completed. In 1867, Mr. Winlock had directed a series of observations with the old meridian circle for the purpose of obtaining an extended list of accurately placed time-stars. The utility of a larger catalogue of time-stars had been evidenced in the operations for the determination of longitude conducted by the United States Coast Survey, of which Mr. Winlock was consulting astronomer. These observations, which assigned exact places to stars only two minutes apart in right-ascension, but differing widely in declination, were finished in December, 1868, and have been reduced and printed. In 1871–72, the same stars were reobserved with the new circle, and again for the third and fourth times in 1874 and 1875. An additional set of stars is required for the instrumental constants, expressing errors in azimuth, collimation, level, etc. For this purpose 5000 observations were made with the new circle in 1873 and 1874, intended to serve as the basis of an improved catalogue of polar stars, and they are now ready for publication. Therefore, no time has been wasted in reaping the full benefits of the new instrument, although the 30,000 observations already made with it are only the first-fruits of the happy devices of Mr. Winlock. These materials, to which must be added a catalogue of new double-stars, dissected by the great refractor, and a most laborious and exhaustive work upon stellar photometry, will magnify the forthcoming volumes of the Annals of the Observatory, and be a worthy monument to the skill and perseverance of the Director and his gifted and faithful coadjutors.

In 1869, Mr. Winlock was instructed by Professor Benjamin Peirce, then Superintendent of the United States Coast Survey, to proceed to Kentucky at the head of a party destined to co-operate with officers of the survey in observing the total eclipse of the sun, on the 7th of August. Mr. Winlock gave his attention, particularly, to the physical aspects of the eclipse, examining the photosphere and the chromosphere with the spectroscope, and taking eighty photographs of the eclipse, in all its phases, seven of them during totality. It was his habit to think out every subject which engaged him for himself; and, when he acted, he seldom followed in the wake of other men. He found good reasons for rejecting the method of photographing which had been tried in Spain on occasion of the total eclipse of 1860, and which other American astronomers were preparing to imitate in 1869. As he wished, most of all, to secure a good picture of the corona, he placed the sensitive plates at the focus of the object-glass, thereby economizing the light, and avoiding the distortion by the eye-piece. His success was highly satisfactory. In the best of the pictures, he immediately recognized the fact that the corona was broader in the direction of the sun's equator than along the axis. He had arranged for obtaining numerous views of the partial phases of the eclipse, in the hope of extracting from them valuable information as to the use of photography in observing the transits of Venus. To this end, he was afterwards authorized by the Superintendent of the Coast Survey to engage Messrs. Alvan Clark and Sons to construct a micrometer, adapted to the nice measurement of distances and positions on the photographic plates. The Annals of the Observatory will contain a description and engraving of this micrometer, and an account of the measures made with it, with various representations of the eclipse copied from the photographs.

At this time, no one except Mr. Winlock had succeeded in obtaining a photograph of the corona during any solar eclipse. Although his photographs were only $\frac{3}{4}$ of an inch in diameter, they seemed to promise measurements, made under a microscope, which would compare favorably with the best that could be furnished by meridian instruments. A larger image would be still better; but this required a telescope of formidable length, and difficult to manipulate. To surmount this obstacle, Mr. Winlock conceived the idea of a horizontal telescope, to be fed by the light from a heliostat. He was convinced that a transparent reflector would be better than a silvered mirror, as it would weaken the light, and supersede the necessity of making the time of exposure inconveniently short. Moreover, as the instantaneous action of the light was often sufficient, the heliostat was unnecessary. Soon after his return from Kentucky he gave an order to the Messrs. Clark and Sons for a lens of four inches in aperture and forty feet in focal length, which, after some preliminary trials at their shop, was ready for use at the Observatory in July, 1870; and, since then, has been in constant employment for procuring photographs of the sun. The lens is mounted upon one pier, the reflector upon another, and the camera upon a third pier. The tube used for excluding the daylight is disconnected from the essential parts, so as not to disturb their stability.

At the request of the Superintendent of the United States Coast Survey, Mr. Winlock organized and directed one of the parties sent to the south of Europe to observe the total eclipse of the sun on December 22, 1870. He selected Jerez de la Frontera, near Cadiz, as a favorable station, and was assisted by one experienced officer of the survey, by several eminent astronomers and physicists, and by one of his own staff at the Observatory. Among the physical and astronomical instruments which he prepared for this expedition was a lens of 32½ feet in focal length, to be used in the manner just described for instantaneous photographs. At this time, Mr. Winlock's method was widely known and highly appreciated, and every party which went into the field to observe this eclipse had decided to dispense with an eye-piece, and photograph in the focus of the object-glass. Unfortunately all the parties, European and American, failed, by reason of bad weather, in obtaining a picture of the corona, except the party in Spain; and there, also, the sky was not favorable for the best results. All the observers who went to India to photograph the total eclipse of 1871 preferred the same method, and were successful. Lord Lindsay applied it at the Mauritius in connection with the horizontal telescope. A telescope of long focus is not a new thing; a telescope placed upon the ground is not a new thing; there is no novelty about the heliostat; more than one person may have discovered the advantage in photographing which belongs to telescopes of great focal length. Nevertheless, the adaptation to photographic purposes of a telescope of long focus, fixed horizontally, and used without an eye-piece or a heliostat, is original, and whatever merit there is in it belongs to Mr. Winlock.

In a former generation, an eclipse of the sun excited the interest of astronomers, as furnishing the means of verifying or correcting the dynamical theory, or giving differences of geographical longitude. It is the consolation of science, that as fast as old fields are exhausted new ones call loudly for cultivation. As soon as one question is settled and curiosity flags, another problem springs into life and a fresh interest is born. The old ambition to fit out a comet with its orbit has yielded to the passion for knowing more about its physical changes and constitution. Now that the law of gravitation asserts an unchallenged supremacy in the solar system, the complex structure of the sun and the origin of the solar radiations claim a share of the astronomer's attention. In this way physical astronomy has acquired a new meaning; and a physical as distinguished from an astronomical observatory, either under the same or an independent superintendence, is one of the necessities of to-day's astronomy. It has been largely in the interest of physical astronomy, in this new sense, that observers have traversed continents, crossed oceans, and taken up their quarters in desolate islands, wherever a total eclipse of the sun or the transit of Venus has invited them. Where special physical observatories have not been started, the old observatories must assume their work, but not to the prejudice of the preferred duties of an astronomical observatory. Mr. Winlock gave a liberal portion of his time to celestial spectroscopy, and stocked the Observatory with the requisite instruments, and of the best class. These little instruments divided with the larger ones the benefits of his inventive spirit. In his two eclipse expeditions, he provided abundantly for the spectroscopic examination of the sun's surroundings, catching the sun itself in the reversal of the lines, and witnessing other interesting transformations. The secret of his success lies in the direction of his rule of having a definite idea of what he wished to do, and the best way of doing it, before going into the field. He went to Spain with the purpose of studying especially that fainter portion of the sun's corona which is outside the limits of the best photography. His experience in the Kentucky expedition had taught him that much valuable time is lost in the brief duration of totality, when the position of the dark or bright lines is registered by means of a scale which must be read and recorded at the time. To meet this difficulty, he invented the simple expedient of graving corresponding lines upon a silver plate, previously graduated by a few standard spectral lines. The differences could be leisurely measured at some future time. This improvement was promptly adopted by the English astronomers, and applied by them to the eclipse of 1870. Mr. Winlock was of opinion that his contrivance would be useful in observing the spectra of comets and nebulæ, and wherever the lines were faint. It might also be convenient for finding declination with meridian instruments. Another device was the use of a mirror to reflect the slit, and enable the observer to place it upon any part of the sun's image without the help of an assistant.

In January, 1854, the Hon. R. C. Winthrop, Chairman of the Committee of the Board of Overseers of Harvard College, appointed to visit the Observatory, reported that the Observatory time was sent to Boston for the regulation of marine chronometers, for the arrangement of railroads, and for the general convenience of the people through a large part of New England. He adds: "The importance of such a system to the business operations of the community can hardly be over-estimated." At this time the signals were sent to Boston by way of Watertown, Brighton, and Roxbury, a circuitous line of twelve miles in length, and the wires were often broken. In 1856, a loop connected the Observatory with the Fitchburg line, and was owned by it until 1862. This has, of course, been available for the occasional transmission of time; but it was designed for the determination of differences of geographical longitude, in connection with the United States Coast Survey; a service which began under the administration of the first Director, and has been continually expanding, until it has taken into its embrace the Pacific coast and the western shore of Europe. In 1866, the necessities of the Coast Survey demanded that the loop should be renewed between the Observatory and the main lines of the country; and this was done at the expense of the survey. From its foundation, the Observatory, in one way or another, had furnished exact time to the community gratuitously; for which, elsewhere, observatories receive a liberal compensation. In 1872, Mr. Winlock introduced improvements which have made this service more widely and constantly useful, and at the same time remunerative. A contract was made for a special wire between Cambridge and Boston, which should not be diverted to any other business. An attachment to the mean-time clock of the Observatory interrupts the voltaic current once in each two seconds, omitting the last break of every minute, and the last thirteen breaks of every five minutes, so that there can be no mistake as to the identity of any second or minute. Branch wires unite the City Hall of Boston, the telegraph offices and railroad depots, and the principal clock and watch factories and warehouses with the first wire. In some places, an electro-magnetic clock is used, controlled by the Observatory clock; but a cheap vibrating armature is all which is necessary, and is generally employed. The superiority of the new system is here: clocks, watches, and chronometers can be compared with the best standard time, not merely once a day, but at any moment; and the public have appreciated and rewarded it. In one sense, it may be always said that time is money. In this instance, the Observatory time has opened so good a market that it has yielded a yearly income of $2000.

In 1872, Mr. Winlock began to prepare a series of astronomical engravings, which should represent, with sufficient accuracy, the most interesting objects in the heavens, as they appear in the powerful instruments of the Observatory. This work was intended for the benefit, not of astronomers, to whom the "Annals" are accessible, and precise measurements are indispensable, but of a larger class of readers, who, without pursuing astronomy as a specialty, are interested in following its progress and achievements. Thirty-five large plates, beautifully executed from the most carefully prepared drawings and photographs, were completed at the time of Mr. Winlock's death, and wait only for a few pages of letter-press to be ready for publication. They will gratify the scientific public with admirable representations of the planets, Mars, Jupiter, and the ring-encompassed Saturn; of the sun's spots, protuberances, and corona; of the moon's craters and geography; of seven of the most famous clusters and nebulæ; of Donati's comet of 1858, and Coggia's comet of 1874, in some of their wonderful transformations.

In August, 1874, Mr. Winlock was appointed by Secretary Bristow chairman of the commission established by Act of Congress for making inquiries into the causes of steam-boiler explosions. He entered into this investigation with remarkable energy; carefully analyzed the various theories which had been suggested to explain this class of accidents; and ended with devising a number of ingenious experiments calculated either to confirm or refute them in detail. The arrangements were nearly completed for making these experiments at Sandy Hook and at Pittsburgh, when death put an end to his labors.

In the early part of his active career, Mr. Winlock was known and trusted as an accomplished teacher and an excellent mathematician; well versed in theoretical astronomy, and capable of applying it in laborious and responsible calculations. These qualifications pointed him out as a proper person to be made director of an observatory. With his new opportunity, he developed other talents, which, if not indispensable, were none the less valuable in his changed condition. It might have been expected that his clear mathematical mind would easily comprehend the physics and the geometry of the instruments whose usefulness he was to guide, and seize upon any defects which might exist in their construction. In devising remedies for these defects, as simple as they were sufficient, he displayed an originality in his mechanical ideas, and a spirit of invention, which left nothing wanting to fill out the measure of a consummate director. Without any passion for innovation, or any conceit of his own methods, he was not afraid to leave an easy and well-worn path, or disturb the most time-hallowed routine, if he could give good reasons for the change. The life of an assistant at an observatory, obliged to work while other men sleep, exposed to the caprices of the clouds, made nervous by the irregularity of his hours, the nice handling of his instruments, and the delicacy of the work expected of him; disappointed at the critical moment in realizing the fruits of anxious days of preparation: such a life is dependent, in no small degree, not only for its happiness, but its endurance even, upon innumerable and indescribable little facilities for observation, which individually are not worth the mention, but which in the aggregate tell distinctly upon the success and the comfort of the profession. In his many innovations, of which every room and each instrument in the Observatory is a witness, Mr. Winlock was not misled by any theoretical abstractions, but moved always within the limits of practical good sense.

In his administrative capacity, which was tested in the Nautical Almanac, at the Observatory, and on two eclipse expeditions, Mr. Winlock evinced a disinterestedness, a strength, and a tranquillity of mind, which commanded the respect and won the affection of his associates. His leadership was nowhere asserted, but everywhere acknowledged. A man of few words, but of much thought; of no pretensions, but of great performance; he did his own part patiently and well, and by his example inspired others to do theirs. The magnitude and the variety of work embraced in his programme, none of which suffered by default, certify to the prudence and the vigor with which his forces were selected and marshalled.

In his private life, Mr. Winlock was exceptionally quiet and retiring. But little inclined to general society, he was full of hospitality. His happiness was not complete without a few very intimate friends; and he had no enemies. He was remarkably silent before strangers; but no one talked more or better in the circles which he loved. Indisposed as he was to take up his pen, when he wrote his words were as transparent as his thoughts. Modest and without self-assertion, he had as much as any other man the courage of his own opinions. Slow to put himself forward, he was genial and accessible; giving his time and his instruction freely to all who asked; never hoarding up a discovery for his own exclusive benefit, but sharing with all his last thought and his newest invention. He was keenly alive to the ridiculous; but there was no ill-nature in his criticisms. Pretence and charlatanism in science amused him; but they did not destroy his equanimity. Without any selfish aims, he took no security for his own discoveries and inventions; so that others, less scrupulous than he was, too often entered into his labors. His friends sometimes wished that his ambition had been more aggressive; but perhaps he was wiser, in the simplicity of his character and the purity of his motives, than the men of this generation. The discoveries and inventions which he did not claim for himself will be vindicated for him.

In an age of bribery and corruption, every example of honor and fidelity in the execution of a public trust is to be cherished. In an age, when superficiality is preferred to depth, when the aspirants for scientific distinction sometimes forget to be just, and even the stars of heaven are obscured by the dust of earth, every life consecrated to honest study, not deflected from its high path by the love of popular applause, silent in its own strength, as the planets whose courses it follows, is a blessing and a legacy to mankind. In an age, when priority of discovery often counts for more than the advancement of human knowledge, and the value of inventions is read only on the patent-rolls, the seeds which are scattered broadcast by the roadside and not selfishly garnered in some private granary, though the sower may have no sense of his own merits, will make the harvest of future science. The deep impression which a quiet, unobtrusive, self-poised career, like that of Mr. Winlock, makes upon the community, can never be known until it is finished. And then we see the beautiful spectacle of all—friends and strangers, those who knew him best, and those who seemed to know him but little—spontaneously offering the tributes of gratitude and affection which they would have refused to the noisy claimant. This is the best hope and the highest reward of science.

Shy soul and stalwart, man of patient will
Through years one hair's-breadth on our Dark to gain,
Who, from the stars he studied not in vain,
Had learned their secret to be strong and still,
Careless of fames that earth's tin trumpets fill;
Born under Leo, broad of build and brain,
He watched while others slept, in that hushed fane
Of Science, only witness of his skill;
Sudden as falls a shooting-star he fell,
But inextinguishable his luminous trace
In mind and heart of all that knew him well.
Happy man's doom! To him the fates were known
Of orbs dim-hovering on the skirts of space,
Unprescient, through God's mercy, of his own![1]

[1] J. R. L.

DATE DUE			